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THE NEXT APPARITION OF HALLEY'S COMET.

H. C. WILSON.

FOR POPULAR ASTRONOMY.

The great comet known as Halley's has a period which has varied from 79 to 74½ years in the last seven centuries, owing to the disturbing effect of the planets Jupiter and Saturn upon its orbit. Its path around the Sun is very elongated; at perihelion the comet is nearer than Venus to the Sun, while at aphelion it is farther off than Neptune, being then thirty-five times as far as the Earth from the Sun. The comet has been observed at each of its apparitions certainly as far back as the year 1222 A. D., and it is extremely probable that the identification of the great comets of 1145 and 1066 with Halley's comet is correct. Back of these the identifications are more or less vague, although two, those of the years 451 and 760 A.D. are fairly certain.

The French astronomer Pontécoulant carried the calculation of the perturbations of this comet back to 1531, and recently* Messrs. Cowell and Crommelin of the Royal Observatory at Greenwich have extended the calculations back to 1222, and are now working on the revolutions 1066-1145 and 1145-1222. The result of these computations has been to prove that Hind's conjecture as to the identity of the comet of 1301 with Halley's is correct, but that his similar identification of the comet 1223 is erroneous, the perihelion of Halley's comet occurring in September 1222 instead of July 1223. "There was, however, a much more remarkable comet which appeared at the exact epoch of the calculation, and examination shows that the greater part of the statements made concerning it by contemporary writers are quite consistent with its being Halley's, so that the identity is placed beyond a reasonable doubt."

Concerning the comets of 1066 and 1145 Messrs. Cowell and Crommelin add this remark: "Though the computations for the revolutions 1066-1145, 1145-1222, are still incomplete, enough has been done to make it extremely probable that

* *Monthly Notices* R.A.S. LXVII. p. 111 and p. 173.

Hind's identification is correct in each case, though his elements of the apparition of 1066 clearly need modification. They differ more widely from the present elements than perturbations will account for. However, the positions are so vaguely recorded that large alterations in them are possible."

We have thus one great comet whose history has been traced back over eight centuries, and in that time it has come to perihelion eleven times and has not failed of being seen and recorded at a single apparition. It has at each return been visible to the naked eye and several times has been a splendid object, creating great interest and even terror among the people who saw it. The tail of the comet has varied very much in appearance at the different apparitions, owing to the different angles at which it was seen and the different background of dark sky or bright twilight against which it was projected. In 1066 it was a "famous object which created universal dread throughout Europe. In England it was looked upon as a presage of the success of the Norman invasion." In 1145 according to the Chinese records, on May 14 it had a tail 10° long. In 1222 it is recorded that in the months of August and September a nine star of the first magnitude, with a large tail, appeared. According to the Chinese the tail was 30 cubits long and the comet remained in sight for two months. In 1301 and 1378 it was visible for six weeks. In 1456 it occupied a space nearly 70° in length, and spread terror throughout Europe, being visible for a month. In 1531 and 1607 it does not appear to have been so conspicuous, the tail being recorded as only 7° long. At the latter of these two apparitions Kepler described the comet as a star of the first magnitude, but so trifling was the tail that it was at first doubted whether it had any. Again in 1682 the comet attracted little attention except among astronomers; the tail was observed as 12° to 16° long. This apparent waning of the comet led astronomers to fear that in 1759, its first predicted return, it might be so faint as not to be visible at all. However the predictions of its course were so accurate that it was found, with the aid of small telescopes, by two observers three months before reaching perihelion. The tail did not become visible until after perihelion and when it should have been brightest was seen against bright twilight and so was not conspicuous, but in the southern hemisphere where the circumstances were more favorable it was visible to the naked eye and its length on one date was estimated at 47°. In

1835 it was visible to the naked eye during the whole of October, with a tail from 20° to 30° long. The question now naturally arises, will the next return, in 1910, be under favorable or unfavorable circumstances? Shall we expect to see a great, magnificent comet as in 1456, or a comparatively insignificant object as in 1607, or will it be an ordinary big comet as it 1835? In order to aid in answering this question I have collected together the elements of the comet's orbit at the different apparitions which have been observed and have drawn the diagram which appears as the Frontispiece of this number of POPULAR ASTRONOMY.

APPROXIMATE ELEMENTS OF HALLEY'S COMET
REDUCED TO THE EQUINOX OF 1910.

Perihelion Passage	Angle from Ascending node to Perihelion	Longitude of Ascending Node	Inclination of Orbit to Ecliptic	Perihelion Distance	Period Years
451 July 3	108.5°	53.3°	16°	0.60	
760 June 11	107.5	52.5	17	0.60	...
1066 Apr. 1	...	...	...	...	...
1145 Apr. 29	...	...	...	...	79.1
1222 Sept. 15	105.6	51.6	16.5	0.67	77.4
1301 Oct. 22	...	...	...	...	79.1
1378 Nov. 8	107.77	54.67	17.9	0.584	77.0
1456 June 8	104.82	50.08	17.62	0.581	77.7
1531 Aug. 25	104.30	50.77	17.00	0.579	75.2
1607 Oct. 27	107 25	52.66	17.14	0.585	76.2
1682 Sept. 14	109.26	54.35	17.76	0.583	74.9
1759 Mar. 12	110.65	55.92	17.62	0.585	76.5
1835 Nov. 16	110.64	56.19	17.76	0.586	76.7
1910 May 10	111.54	57.18	17.78	0.59	74.5

Motion retrograde.

The diagram was prepared by the aid of ephemerides of the comet computed by Mr. F. E. Seagrave of Providence, Rhode Island, and the elements differ slightly from those given in the last line of the table, but not enough to affect the shape of the diagram appreciably. Mr. Seagrave adopts May 10 for the date when the comet will be at perihelion. The computations of Messrs. Cowell and Crommelin point to an earlier date, probably about April 8 for perihelion passage. Comparing this with the dates in the table we see that this coincides very closely with that for the apparition in 1066 when the comet was a famous object.

According to the table, if we accept the records of 451 and 760 as being genuine records of Halley's comet, it has been at perihelion in all the months of the year except January, February, May and December. The great displays appear to have been when the perihelion passage occurred in April, June, July

and November. The reasons for this will be plain to one who studies the diagram. The dotted curved line represents that portion of the comet's orbit which lies below the plane of the ecliptic; the smooth curve, including the dates February 12 to June 3, is above that plane. The inclination of the comet's orbit to the ecliptic being about 18°, the reader must think of that part of the diagram as being tilted out of the plane of the paper, revolved about the line of nodes through the angle 18°, so that the point marked May 2 would be about the highest point of the curve. Now imagine the Earth to be moving in the plane of the paper and the comet in the tilted curve, and to pass the perihelion point (marked May 10 in the diagram) about April 1. It takes the comet about 40 days to pass from its perihelion out to the Earth's distance from the Sun, so that it would reach the nearest point to the Earth's path about May 11 and during the first half of May the two bodies would be relatively close together; the nearest approach that could occur would be about May 4, when the comet, if it were directly below the Earth, would be roughly 6,000,000 miles away. A few days' change in the date of perihelion would here produce a very great change in the comet's apparent course through the heavens. If perihelion should be a few days before the first of April, the comet would cross in front of the Earth and so be seen in parts of the sky far from the Sun when nearest the Earth. In 1759 the passage occurred too early and in 1145 too late, if the date be correct, for the most magnificent effect.

For the perihelion passages in June and July it will be noticed that the comet is nearest the Earth just after or close to the time of perihelion when the tail has its greatest development, and also when the comet is near its highest elevation above the ecliptic, so that even when in conjunction with the Sun it is so far north as to be visible both evening and morning. In 1456 it was for a time circumpolar so that it could be seen above the northern horizon all night.

In August, September and October the conditions are even better so far as position in the sky is concerned but the nearest approach to the Earth occurs before the greatest development of the tail has been reached. For a November perihelion, especially in the latter part of the month, the favorable position of the comet in the sky during October largely offsets the lack of development of the tail, and so the apparition in 1835 was a favorable one. Had the comet passed the

Earth two weeks later than it did its distance on October 20 would have been only 15,000,000 miles and its tail might have appeared much larger than it did.

Now as to the 1910 apparition. The comet is now out between the orbits of Jupiter and Saturn. It will be within the distance of Jupiter's orbit after March 1, 1909. It is possible that some one with the aid of a great telescope or a photographic camera may catch sight of the expected visitor during the winter of 1908-09. We may begin to search for it as early as September 1908, provided good ephemerides are at hand. Almost certainly it may be found by September or October 1909. It will then be only a round nebula, whatever tail it has being almost directly behind it as seen from the Earth. If the date of perihelion should be May 10, the comet will be lost behind the Sun in the early part of April, reappearing in the morning sky about the first day of May. It should reach its greatest brilliancy in the last days of May but the morning dawn will prevent its having the most striking effect. It will pass between the Earth and the Sun about June 1 and there is a possibility then of the tail extending so far out over the Earth that it may be very conspicuous in spite of the deep twilight in which the head of the comet must be observed. After June first the comet should be visible in the evening in the western sky, a more or less splendid object according as the effect of the lessening twilight or the increasing distance of the comet be the more important factor in changing its brilliancy.

If the date of perihelion should be April 8, as Messrs. Cowell and Crommelin predict, the circumstances may be quite different. We must then diminish all the dates on the diagram of the comet's path by thirty-two days. The comet will be lost in the twilight in March and reappear from the dawn in April. It will approach much closer to the Earth as it passes between the Earth and the Sun in May, but will be much more nearly in line with the Sun, so that at the time of conjunction we shall probably not be able to see it at all for two or three days. For a few days before this, i. e., about May 1 it should be a splendid morning comet and during the latter half of May it should be a fine object in the evening.

One fact which will strike the eye of the reader at once upon examining the table of elements of Halley's comet, which I have given above, is the great change in the period of the comet which may occur from one revolution to the next. It

has in some cases amounted to more than two years, and it does not continue in the same direction in successive revolutions but sometimes increases and sometimes decreases the period. The longest revolution so far recorded is that of 1222-1301 and that of 1066-1145 is very near the same, 79 years and one month. The shortest round is the one now being accomplished, being a little less than 74 years six months. This extreme range of over four years in the period renders necessary the most careful and laborious calculation of the effects of the attraction of all the planets upon the comet, and it seems a marvel that the computers have come so near to predicting the exact date of perihelion at previous apparitions. In 1759 Clairaut and Lalande predicted a date twenty-three days too late, but Laplace has since shown that if the mass of Saturn had been accurately known at the time when the computations were made, the error of the final result would have been within nine days. The planets Uranus and Neptune were then unknown so that their influence was entirely neglected. In 1835 five computers obtained different dates ranging from October 31 to November 26. The actual perihelion occurred November 16 so that all were within sixteen days of the true date. Pontécoulant predicted November 14 and so was only two days in error. If the computers for 1910 can beat this record they will do well.

Halley's comet is sometimes spoken of as one of the Neptune family of comets. As a matter of fact Neptune, as the orbit of the comet is now situated, can have very little influence in disturbing it. The inclination of the comet's path is such that it nowhere approaches closer than 750,000,000 miles to Neptune's path. Both the nodes are near the other end of the orbit, near the paths of Earth, Venus and Mars and these little planets have more influence upon the comet's motion than can Neptune have. It is difficult to see therefore how Neptune can have been instrumental in capturing this comet. It is true there is some indication of a shift of the line of nodes around the orbit, and in long ages past the descending node may have been in the vicinity of Neptune; in any case the time is very remote.

THE SOLAR ECLIPSE OF JUNE 28, 1908 AS VISIBLE IN THE UNITED STATES.

Wm. F. RIGGE, S. J.

For Popular Astronomy.

The solar eclipse of June 28, 1908 will be well visible all over the United States. The Sun will everywhere be high in the sky, and the magnitude of the eclipse will vary from one-tenth in the state of Washington to the annular phase in Florida. The accompanying maps will probably furnish all the information desirable.

Figure 1 shows the central time of the beginning of the eclipse, as well as the position of the point of first contact. The full lines denote the time, the large numbers 8 and 9 representing the hours 8 and 9 o'clock in the morning, and the smaller ones, 10, 20, 30, 40, 50, the intervening minutes. By means of these lines the time of the beginning of the eclipse may be found for any locality to the nearest minute. It need hardly be said that Eastern time will be one hour later and Mountain and Pacific times respectively one and two hours earlier than the central time shown on the map.

The "one-dot-and-one-dash" lines, marked N 200 to N 260, indicate the position angles of the point of first contact on the Sun's limb, counting from the north point towards the east. The "three-dot-and-one-dash" lines, marked V 240 to V 350, show the same point of first contact as measured from the Sun's vertex or uppermost point, also towards the east.

Figure 2 gives the time of the middle of the eclipse, that is, the time of the maximum obscuration, together with its amount. The large numbers 9 and 10 mean, as before, 9 and 10 o'clock, and the smaller ones, 10, 20, 30, 40, 50, the intervening and subsequent minutes. The other numbers, from 1 to 9, denote the magnitude of the eclipse as expressed in tenths of the Sun's diameter obscured. The appearances of the Sun thus variously eclipsed are shown in Figure 3.

The belt on Figure 2 marked Annular Eclipse shows where the Moon will be seen to completely enter the Sun's disk but unable to obscure the whole of it. On the border lines of this path the Moon will just graze the Sun's limb, and the eclipse

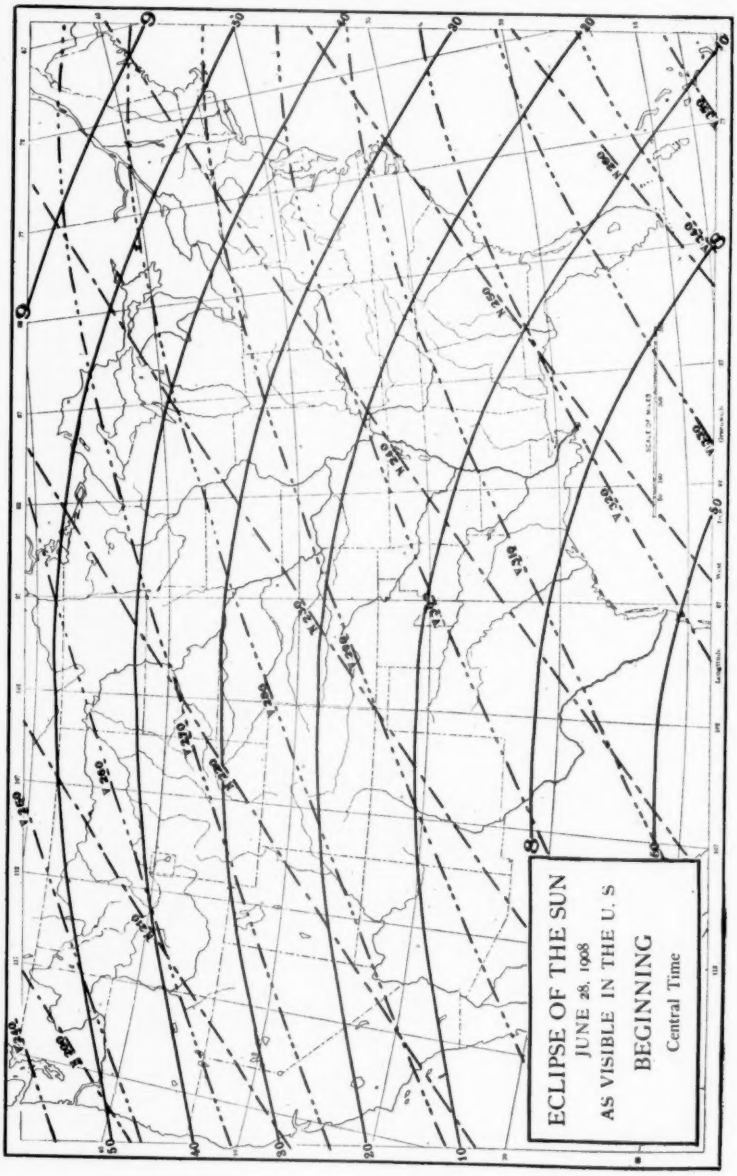

ECLIPSE OF THE SUN
JUNE 28, 1908
AS VISIBLE IN THE U. S
BEGINNING
Central Time

FIGURE 1.

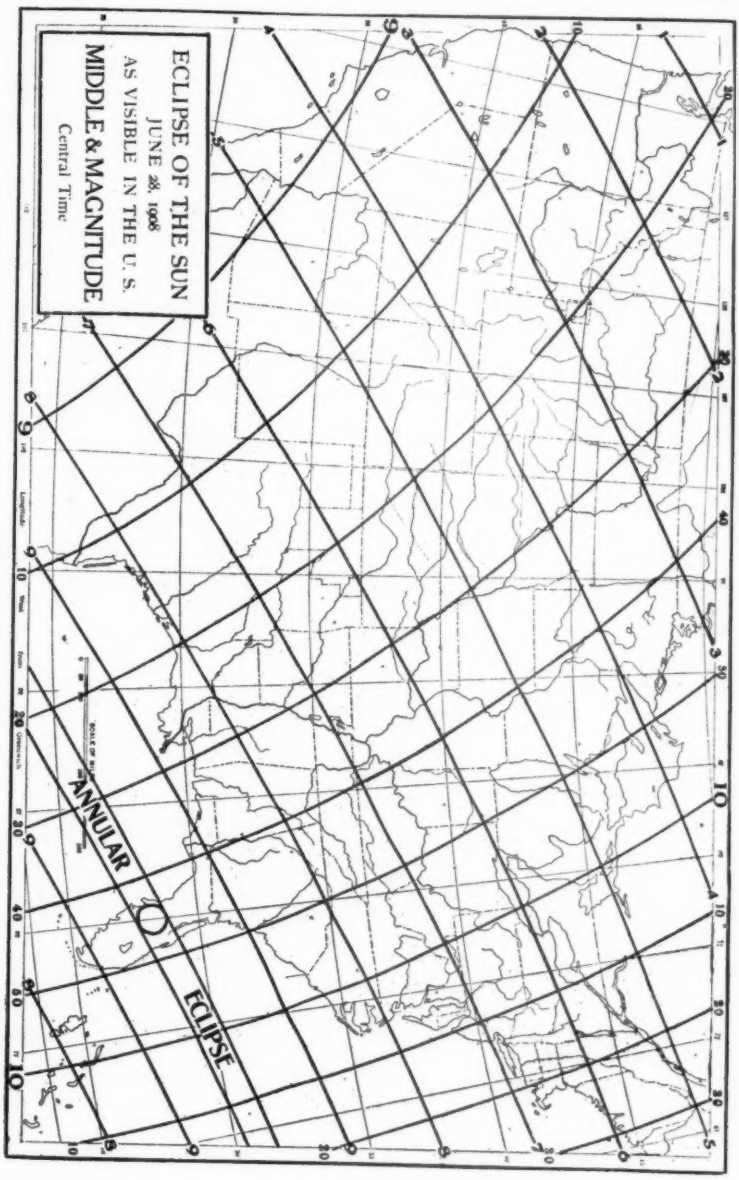

ECLIPSE OF THE SUN
JUNE 28, 1908
AS VISIBLE IN THE U. S.
MIDDLE & MAGNITUDE
Central Time
ANNULAR
ECLIPSE

FIGURE 2.

will appear as shown in the last but one drawing on Figure 3. On the central line of the annulus path, which has not been drawn on Figure 2, but which may easily be supplied by estimation, the Moon's center will be seen to pass exactly over the Sun's center, and the Sun will appear as a narrow ring of light, for which reason this is called an annular, or ring, eclipse. This is illustrated in the last drawing on Figure 3. The small ellipse on Figure 2 shows the extent of country where the annular eclipse will be seen at the same moment, the time being $9^h\ 45^m\ 0^s$.

As such an annular eclipse is quite a rare and most beautiful sight and well worth a journey of many miles to see, a very detailed map of the path of this eclipse across the narrow peninsula of Florida will be found in Figure 4. This map has been prepared at great pains from the latest and large wall map of the United States as issued by the General Land Office of the Department of the Interior, corrected to June 30, 1905. The scale of this map is 25.9 miles to an inch.

After plotting the central and border lines of the annulus path as given in the *American Ephemeris* directly on the original map, a copy of the eclipse region was made by measuring the position and length of all the necessary range and township lines down to the one-six-hundredth part of an inch, and transferring these measurements to Figure 4 under a three-fold enlargement. As the latitude and longitude lines were found to be slightly unevenly spaced on the government map, it was judged better to reproduce the eclipse region exactly as it lay, rather than introduce any personal, although justifiable, alterations.

The cities and towns were plotted with reference to the range and township lines, and these lines were allowed to remain on the map in order to serve for the insertion of smaller unmentioned places, as well as furnish a scale of measurement and orientation, although a considerable irregularity was detected among them on the government map. The broken lines connecting the towns show the Florida railroad system. After all the data to be found upon the government map had been transferred to Figure 4, the boundaries of the counties and the names of many other towns, taken mainly from Rand McNally & Co.'s New Family Atlas, 1891, and a few from the Columbian Atlas, 1898, were added in script.

The numbers 28 and 29 on the border of the map indicate the 28th and 29th parallels of north latitude, and the numbers

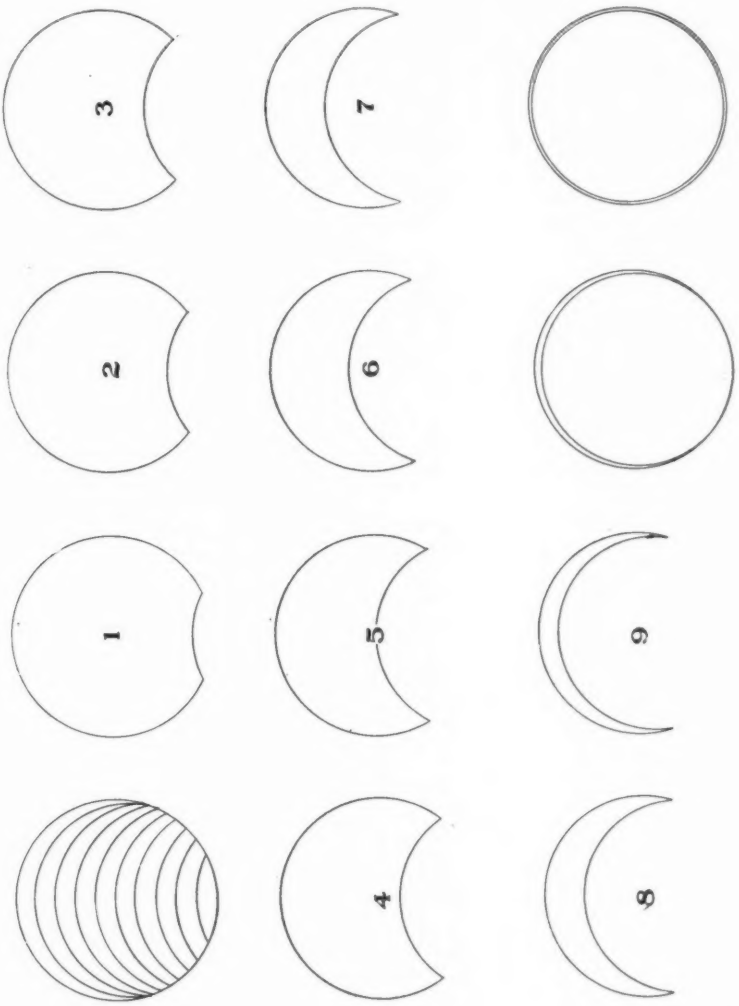


FIGURE 3. APPEARANCES OF THE SUN AS VARIOUS TENTHS OF ITS DIAMETER ARE ECLIPSED.

81, 82, 83, the corresponding meridians of longitude west of Greenwich. The line running through the middle of the map and marked 42 to 49, is the central line of the eclipse, and these numbers mean the corresponding minutes after 9 o'clock in the morning, central time, or after 10 o'clock, eastern time, when the annular eclipse will be central at these points. The other two lines parallel to the central line are the northern and southern limits of the annulus path, outside of which the eclipse will not be annular. The lines passing through the numbers on the central line and extending from one limit line to the other, are the mid-phase lines. By measuring the distance of a place from any of these mid-phase lines in a direction parallel to the central line and on the scale marked thereon, the time of the middle of the eclipse may be found to the nearest second.

The extent of the region covered by the negative shadow at 9 o'clock 45 minutes is shown by the large ellipse centered at number 45, in latitude 28° 11′.2 and longitude 81° 54′.8. The known duration of the eclipse at this place gave the diameter on the central line, and the mid-phase line gave its conjugate, which together with the angle between them furnished the major and minor axes and thus permitted of its construction. As a test of the accuracy of this computation and the preceding graphic measurement, the major axis was found to be exactly equal to the minor axis multiplied by the secant of the Sun's zenith distance, 24° 25′, and to lie within one degree of the Sun's azimuth, S 81° 10′ E. The local hour angle was found to be 26° 24′ or $1^h\ 45^m.6$ east, giving $10^h\ 14^m.4$ as the apparent solar time.

The duration of the annular phase may be found for any place by drawing a line through it and the ellipse parallel to the central line, and measuring the length of the chord on the time scale shown on the central line. But owing to the slight distortion referred to above, the varying separation of the limit lines and the consequent variation of the ellipse this method is not very reliable. To correct these errors to some extent a scale has been placed on the mid-phase lines 42, 45 and 49. The numbers 30, 1:00, 1:30, mean 30^s, $1^m\ 00^s$, $1^m\ 30^s$, and together with their intermediate 10 seconds' marks, indicate for places at their respective distances from the central line, the time that the annular phase will begin before and cease after the time of the middle of the eclipse, and hence give the half duration of the annular phase.

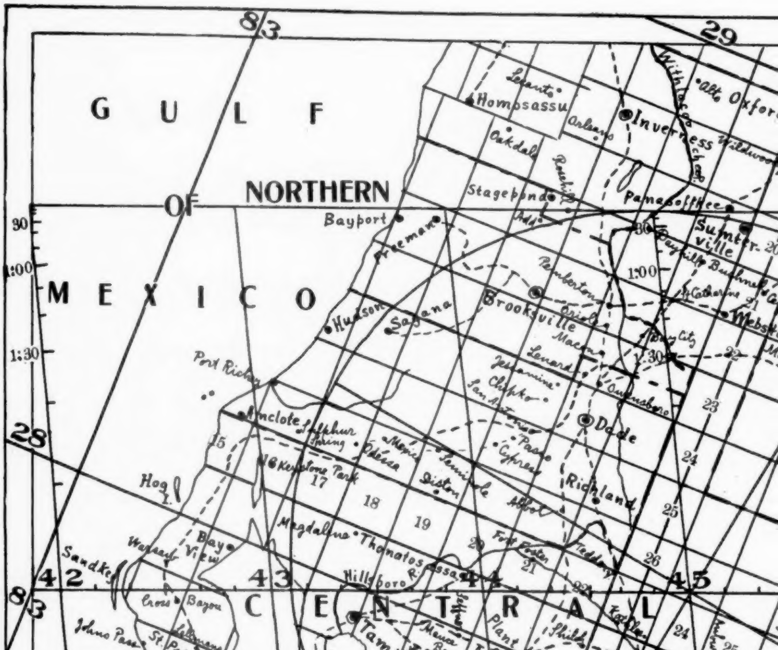
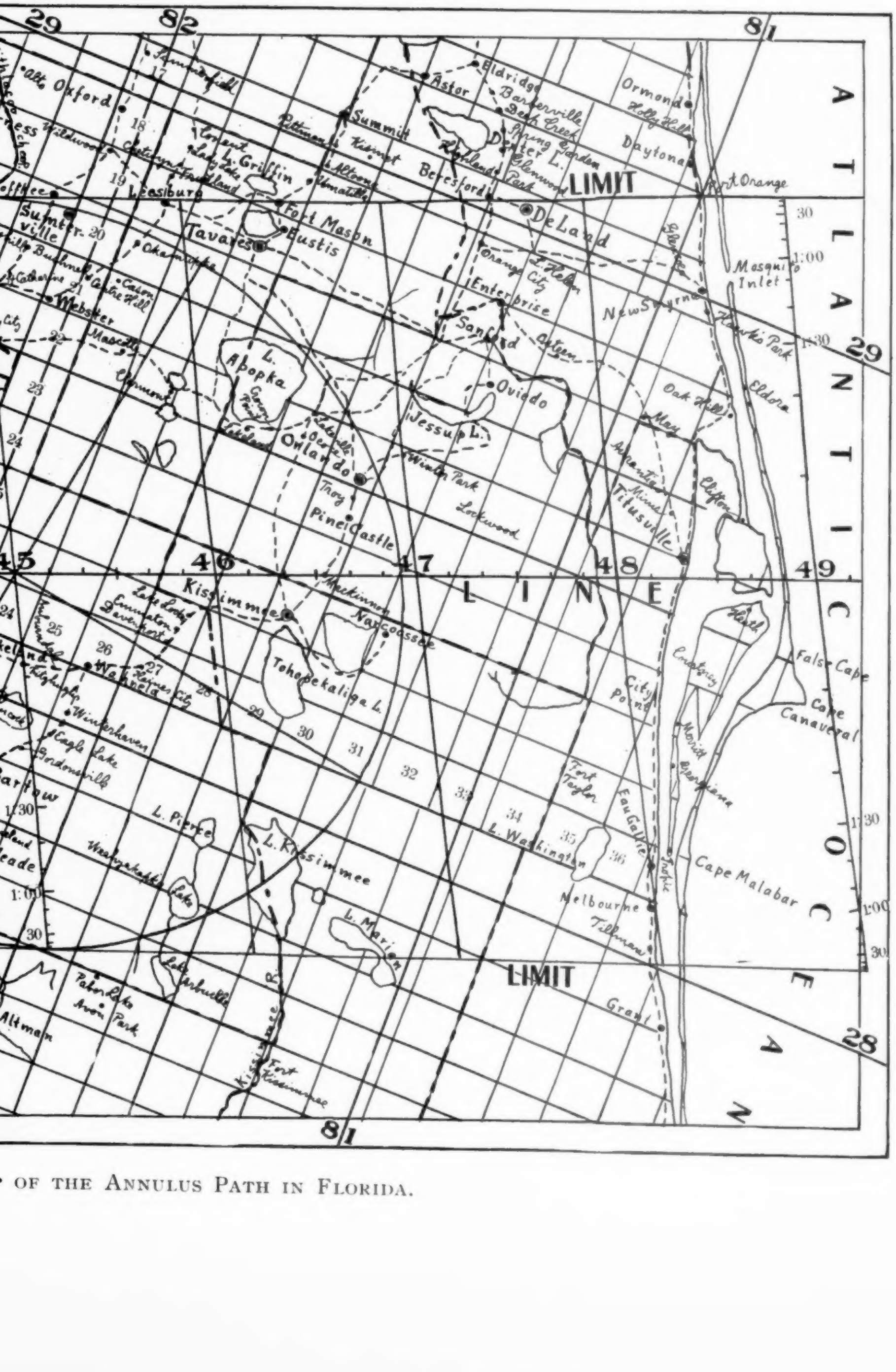


FIGURE 4, MAP OF THE



OF THE ANNULUS PATH IN FLORIDA.

In order then to find this time for any particular place, its distance from the central and limit lines ought to be measured in a direction parallel to the mid-phase lines, and the scale corrected in proportion. And finally, as another element of variation is introduced by the variable duration of the eclipse on the central line, being

3m	49s.0	at	9h 42
	49.4		43
	49.8		44
	50.2		45
	50.6		46
	51.0		47
	51.4		48
	51.8		49

the graphic method cannot reasonably be expected to be correct within ten seconds for places very close to the border, such as Bayport and DeLand, while for places near the central line, such as Tampa and Titusville, it may probably give the nearest second or two.

In an annular eclipse the vertex of the Moon's shadow cone does not reach the Earth. When this cone is produced beyond the vertex, it forms what is termed the negative shadow, which of course is no true shadow but a part of the penumbra. The cross section of this negative shadow cone increases as it approaches the Earth and hence is smaller on the surface of the Earth than it is on the fundamental plane which passes through the Earth's center. This fact reduces the width of the Sun's annulus. In the present eclipse the Sun's semidiameter is 15′ 43″.8, and the width of the annulus 47″.0 as seen on the fundamental plane, but only 33″.7 as seen in Florida. The Sun will there appear to be a ring whose width is one-fifty-sixth of its diameter, 0.0178. It may be of interest to state that the place No. 45 on Figure 4 is the distance 0.91060 of a terrestrial radius above the fundamental plane at the time mentioned, and the vertex of the Moon's shadow 3.118 terrestrial radii above the same plane.

Finally Figure 5 gives the time of the end of the eclipse all over the United States.

The following examples may serve to illustrate the use of these eclipse maps.

Place	Time	Beginning		Position Angles		Middle		Magnitude	End	
		h	m	°	°	h	m		h	m
Washington	Eastern	9	36	N 244	V 300	11	04	0.72	12	50
Omaha	Central	8	26	N 228	V 284	9	31	0.50	11	01
Denver	Mountain	7	22	N 224	V 281	8	17	9.45	9	40
San Francisco	Pacific	6	27	N 212	V 268	7	03	0.28	8	06

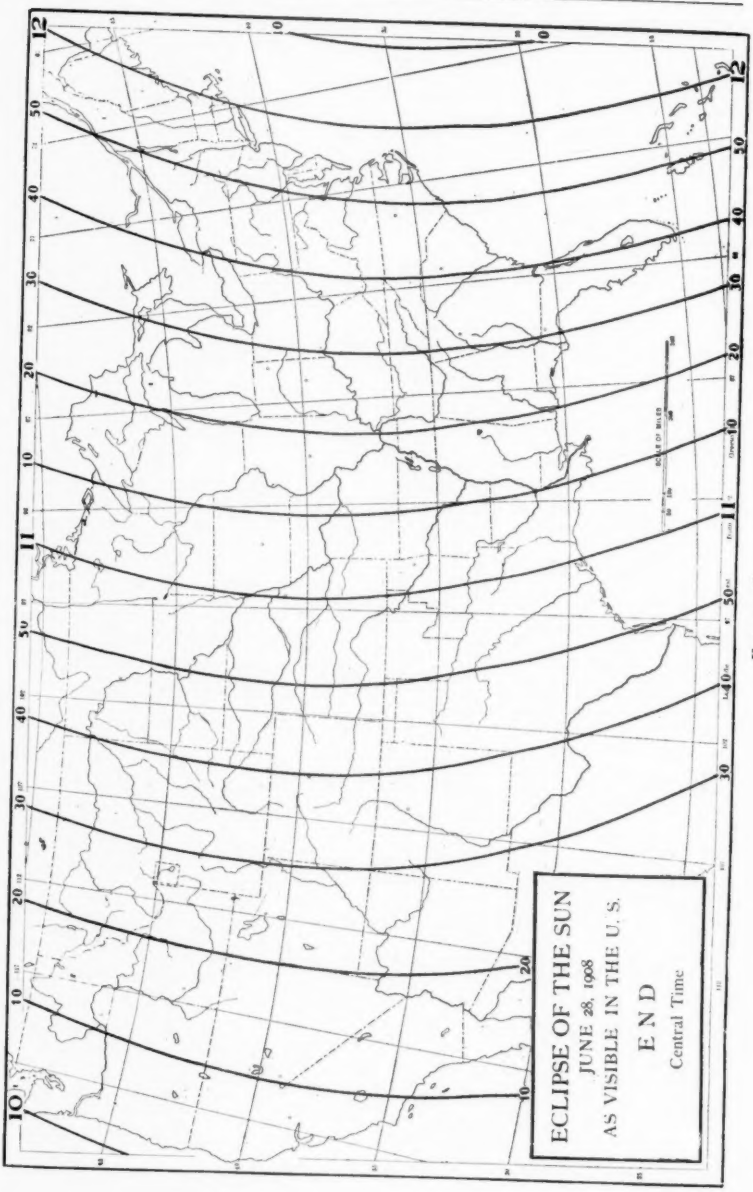

ECLIPSE OF THE SUN
JUNE 28, 1908
AS VISIBLE IN THE U. S.
E N D
Central Time

FIGURE 5

ANNULAR ECLIPSE.

Place	Beginning		Middle		End		Duration	
	m	s	m	s	m	s	m	s
Tampa	41	28	43	23	45	18	3	49
DeLand	47	20	47	43	48	06	0	46

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THE PATH OF THE SHADOW OF A PLUMMET BEAD.*

ELLEN HAYES.

The actual determination of a north-and-south line is one of the most valuable exercises for the beginner in elementary practical astronomy; and of the various methods there is perhaps none more satisfactory than that which consists in the use of shadows cast on a horizontal surface by the end of a vertical pin, or by a bead on a plumb-line. Theoretically, of course, only two shadows of equal length are necessary, but in practice it is a good plan to mark the shadow-points for a number of positions of the shadow of the bead. The curve obtained by connecting these points cannot fail to attract the observer's attention. It is evident from mere geometrical considerations that the curve will be a conic section, in general, a hyperbola. Analysis, however, has here its usual advantage over a geometrical treatment of the case, and the equation to the curve is invested with more than usual interest, since the coefficients are functions of the observer's latitude and the declination of the Sun. The equation may be obtained as follows:

From Chauvenet's *Astronomy*, Vol. 1, Sec. 14, we have the familiar formulas,

$$\cos\phi \cos\delta \cos t = \cos\zeta - \sin\phi \sin\delta \qquad (1)$$

$$\cos\phi \cos\delta \cos t = \sin\zeta \cos A + \cos\phi \sin\delta \qquad (2)$$

in which t is the Sun's hour angle, A its azimuth, ζ its zenith distance, δ its declination, and ϕ the observer's latitude. Dividing eq. (2) by eq. (1),

* Read before Section A, American Association for the Advancement of Science, December, 1904.

$$\tan\phi = \frac{\sin\zeta\cos A + \cos\phi\sin\delta}{\cos\zeta - \sin\phi\sin\delta}. \qquad (3)$$

If h is the height of the bead above the horizontal plane, and ρ the distance of the shadow-point from the point in which the plumb-line meets the plane,

$$\frac{\rho}{h} = \tan\zeta = \frac{\sin\zeta}{\sqrt{1-\sin^2\zeta}}$$

and

$$\rho^2 - \rho^2\sin^2\zeta = h^2\sin^2\zeta;$$

hence

$$\sin\zeta = \frac{\rho}{\sqrt{h^2+\rho^2}}.$$

Only the plus sign is retained after extracting the square root because ζ is always positive.
Also,

$$\frac{\rho}{h} = \frac{\sqrt{1-\cos^2\zeta}}{\cos\zeta}$$

and hence

$$\cos\zeta = \frac{h}{\sqrt{h^2+\rho^2}}.$$

Only the plus sign is here retained because ζ is less than 90° when the Sun is above the horizon.

Substituting these values of sin ζ and cos ζ in eq. (3),

$$\tan\phi = \frac{\frac{\rho}{\sqrt{h^2+\rho^2}}\cos A + \cos\phi\sin\delta}{\frac{h}{\sqrt{h^2+\rho^2}} - \sin\phi\sin\delta}. \qquad (4)$$

This is a polar equation to the path of the shadow with A as the vectorial angle and ρ the radius vector. In place of A, which is measured from the south westward, we may write $\theta = -(180° - A)$. The vectorial angle is then measured from the north counter-clockwise. At the same time the sign of ρ must be changed. Substituting $-\cos\theta$ for cos A and $-\rho$ for ρ, eq. (4) becomes

$$\tan\phi = \frac{\frac{\rho}{\sqrt{h^2+\rho^2}}\cos\theta + \cos\phi\sin\delta}{\frac{h}{\sqrt{h^2+\rho^2}} - \sin\phi\sin\delta} \qquad (5)$$

which is precisely what we had to begin with, so far as form is concerned. This polar equation may now be transformed

to one in rectangular coördinates with the pole as origin and the north-and-south line for the x-axis, the north being taken as the positive end. Introducing the usual relations,

$$x = \rho \cos \theta, \quad y = \rho \sin \theta, \quad x^2 + y^2 = \rho^2,$$

eq. (5) becomes

$$\tan \phi = \frac{\frac{\sqrt{x^2+y^2}}{\sqrt{h^2+x^2+y^2}} \cdot \frac{x}{\sqrt{x^2+y^2}} + \cos \phi \sin \delta}{\frac{h}{\sqrt{h^2+x^2+y^2}} - \sin \phi \sin \delta}$$

or

$$\frac{h \tan \phi}{\sqrt{h^2+x^2+y^2}} - \tan \phi \sin \phi \sin \delta = \frac{x}{\sqrt{h^2+x^2+y^2}} + \cos \phi \sin \delta$$

i. e.,
$$\frac{h \tan \phi - x}{\sqrt{h^2+x^2+y^2}} = \cos \phi \sin \delta + \frac{\sin^2 \phi}{\cos \phi} \sin \delta$$
$$= \sin \delta \sec \phi.$$

From which we obtain

$$h^2 \tan^2 \phi - 2h \tan \phi \, x + x^2 = (h^2 + x^2 + y^2) \sin^2 \delta \sec^2 \phi ,$$

or,

$$(1 - \sin^2 \delta \sec^2 \phi) \, x^2 - \sin^2 \delta \sec^2 \phi \, y^2 - 2h \tan \phi \, x + h^2 \tan^2 \phi - h^2 \sin^2 \delta \sec^2 \phi = 0.$$

The absolute term readily reduces to

$$\frac{h^2}{\cos^2 \phi} \sin (\phi + \delta) \sin (\phi - \delta),$$

so that finally we have

$$(1 - \sin^2 \delta \sec^2 \phi) \, x^2 - \sin^2 \delta \sec^2 \phi \, y^2 - 2h \tan \phi \, x + \frac{h^2}{\cos^2 \phi} \sin (\phi + \delta) \sin (\phi - \delta) = 0 \qquad (6)$$

In discussing this equation it is only necessary to consider the northern hemisphere.

Since the coefficient of y^2 is always minus, three cases arise, according as the coefficient of x^2 is $+$, 0, $-$; that is, according as

$$\sin^2 \delta \sec^2 \phi \lessgtr 1.$$

When
$$\sin^2 \delta \sec \phi = 1,$$

the coefficient of x^2 vanishes and the curve is a parabola. This condition may be stated:

$$\sin \delta = \cos \phi; \text{ i. e., } \phi = 90^\circ - \delta.$$

The maximum value of δ being ϵ, the obliquity of the ecliptic, the lowest latitude in which the curve can be a parabola is that of the arctic circle and it is a parabola on that circle only at the time of the summer solstice. The parabola travels northward at the same rate that the Sun's declination decreases. Behind it, that is, for plumb-lines in more southern latitudes, follow hyperbolas; and ahead of it, to the north, the curves are ellipses. For, if $\phi < 90° - \delta$, $\cos \phi > \sin \delta$, and hence $1 > \sin^2 \delta \sec^2 \phi$, and consequently the coefficients of x^2 and y^2 have unlike signs. On the other hand, if $\phi > 90° - \delta$, $1 < \sin^2 \delta \sec^2 \phi$, and the coefficients have like signs. Hence, in the "land of the midnight Sun" so long as the plumb-line is in a latitude greater than the complement of the Sun's declination, the path of the shadow of the bead is an ellipse, becoming a circle at the pole. These conclusions may also be reached by observing that lines parallel to the asymptotes of the hyperbola are

$$(1 - \sin^2 \delta \sec^2 \phi)\ x^2 - \sin^2 \delta \sec^2 \phi\ y^2 = 0$$

or,

$$y = \pm \frac{\sqrt{1 - \sin^2 \delta \sec^2 \phi}}{\sin \delta \sec \phi}\, x \qquad (7)$$

hence,

$$\frac{b}{a} = \frac{\sqrt{1 - \sin^2 \delta \sec^2 \phi}}{\sin \delta \sec \phi}$$

and

$$e = \sqrt{\frac{a^2 + b^2}{a^2}} = \frac{1}{\sin \delta \sec \phi} = \frac{\cos \phi}{\sin \delta}, \qquad (8)$$

that is, the eccentricity varies directly as the cosine of the latitude and inversely as the sine of the declination;

and $e > = < 1$ according as $\phi < = > (90° - \delta)$.

If we write the equation in the form

$$x^2 - \frac{\sin^2 \delta \sec^2 \phi}{1 - \sin^2 \delta \sec^2 \phi}\, y^2 - \frac{2h \tan \phi}{1 - \sin^2 \delta \sec^2 \phi}\, x$$

$$+ \frac{h^2}{\cos^2 \phi}\ \frac{\sin (\phi + \delta) \sin (\phi - \delta)}{1 - \sin^2 \delta \sec^2 \phi} = 0,$$

and make $\phi = 90°$, the coefficients of y^2 and x take the form $\frac{\infty}{\infty}$ and the absolute term contains the expression, $0.\infty$. Evaluating these indeterminate forms in the usual manner, the equation becomes

$$x^2 + y^2 - h^2 \cot^2 \delta = 0 \qquad (9)$$

that is, the radius of the circle is $h \cot \delta$, as evidently it ought to be when we remember that at the north pole the Sun's altitude equals its declination.

On the equator $\phi = 0°$, and the equation reduces to

$$(1 - \sin^2 \delta)\, x^2 - \sin^2 \delta \; y^2 - h^2 \sin^2 \delta = 0;$$

or,

$$x^2 - \tan^2 \delta \, y^2 - h^2 \tan^2 \delta = 0 \qquad (10)$$

and the center of the hyperbola is now directly underneath the plumb-bob. Also, the asymptotes are

$$y = \pm \cot \delta \; x \, ;$$

that is, the asymptotes make with the east-and-west line an angle equal to the declination of the Sun. The sunrise and sunset shadows of course coincide with these asymptotes.

At the equinoxes $\delta = 0$, and the equation becomes for all latitudes,

$$x^2 - 2h \tan \phi \, x + h^2 \tan^2 \phi = 0.$$

Hence, the shadow-path consists of two coincident straight lines

$$x - h \tan \phi = 0 \qquad (11)$$

that is, an east-and-west line distant $h \tan \phi$ from the point where the plumb-line meets the plane, and on the north side of that point. It follows that on March 21 and September 23 *any* two points, say two forenoon points, will enable us to draw an east-and-west line.

This degenerate form of the generic hyperbola must be regarded as the fundamental one since it is also the path of the shadow of the bead if the *mean* Sun could shine on it. This fictitious mean-sun shadow is thus seen to be a straight line not merely at the equinoxes but on all days of the year, with its position depending only on the latitude of the plumb-line and, of course, on the height of the bead above the plane.

If $\phi = \delta$ the absolute term of the equation vanishes. Hence, when the Sun's declination equals the latitude of any place within the torrid zone the curve for that day passes through the origin, and the noon shadow is merely the projection of the bead on the horizontal plane. This agrees with the obvious geometrical requirements of the case.

Thus far no distinction has been made between summer and winter. It may now be noticed that only the *squares* of the

declination factor appear in the coefficients of the equation. As a consequence, the days of the year go in pairs. That is, if on any day of the year between the vernal equinox and the following autumnal equinox the Sun's declination is δ', we have for any latitude, ϕ', a hyperbola of definite eccentricity and transverse axis, and for the winter day when the Sun's declination is $-\delta'$ the hyperbola is precisely the same as regards dimensions and position. But we know experimentally that the meridian shadow of a gnomon of given height is longer in winter than in summer. We are thus led to the conclusion that the south branch of the hyperbola is the actual shadow-path when the Sun's declination is δ', and the north branch the path when the declination is $-\delta'$.

Making $y = 0$ in eq. (6) and solving for x we have the meridian values of x, namely:

$$x_1 = \frac{h \tan \phi}{1 - \sin^2 \delta \sec^2 \phi} \pm \frac{h}{1 - \sin^2 \delta \sec^2 \phi} \sqrt{\tan^2 \phi - (\cos^2 \delta \tan^2 \phi - \sin^2 \delta)(1 - \sin^2 \delta \sec^2 \phi)}$$

The expression beneath the radical sign reduces to $\sec^4 \phi \cos^2 \delta \sin^2 \delta$, hence

$$x_1 = \frac{h}{1 - \sin^2 \delta \sec^2 \phi} (\tan \phi \pm \sec^2 \phi \cos \delta \sin \delta \qquad (12)$$

These values of x_1 are the two intercepts on the meridian axis. One-half their sum,

$$\frac{h \tan \phi}{1 - \sin^2 \delta \sec^2 \phi}$$

is the distance of the center of the hyperbola from the origin. Since the x corresponding to an actual shadow must have the greater value when δ is negative, the plus sign in eq. (12) is rejected for both summer and winter, and we have simply

$$x_1 = \frac{h}{1 - \sin^2 \delta \sec^2 \phi} (\tan \phi - \sec^2 \phi \cos \delta \sin \delta) \qquad (13)$$

This conclusion is verified by noticing that for ζ_1, the Sun's meridian zenith distance,

$$\frac{x_1}{h} = \tan \zeta_1;$$

and that for summer time

$$\phi = \zeta + \delta$$

while for winter time

$$\phi = \zeta - \delta ;$$

that is, for summer time

$$x = h \tan (\phi - \delta)$$

and for winter time

$$x = h \tan (\phi + \delta).$$

We can now compare these differently derived values of x by writing

$$\tan (\phi - \delta) = \frac{\tan \phi - \sec^2 \phi \cos \delta \sin \delta}{1 - \sin^2 \delta \sec^2 \phi}$$

δ being positive. An identity results from this statement and the assumption of equality is therefore justified. If we suppose δ negative we have a second identity.

If $\tan \phi < \sec^2 \phi \cos \delta \sin \delta$,

x_1 is negative and the shadow falls on the south side of the plumb-line. This condition readily reduces to

$$\sin 2\phi < \sin 2\delta ; \quad \text{that is,} \quad \phi < \delta.$$

This is only possible south of the tropic of cancer, during the summer time. The same result may be reached by noting the intercepts on the east-and-west axis.

Making $x = 0$ in eq. (6),

$$y = \pm \frac{h}{\sin \delta} \sqrt{\sin (\phi + \delta) \sin \phi - \delta} ;$$

hence, if $\phi < \delta$, y is imaginary, and the shadow-path must lie wholly on the south side of the east-and-west axis.

If we introduce into eq. (6) the condition, $\delta = 90° - \phi$, we have

$$y^2 + 2h \tan \phi \, x + h^2 (1 - \tan^2 \phi) = 0.$$

The parabola is seen to be convex northward, since the intercepts on the east-and-west axis are real, $1 - \tan^2 \phi$ being now a negative quantity. Also, the distance from the origin to the vertex of the curve is

$$\frac{h(1 - \tan^2 \phi)}{2 \tan \phi} .$$

This result may be obtained independently by observing that the meridian altitude of the Sun is 2δ if $\delta = 90° - \phi$; and hence

$$\frac{h}{x^1} = \tan 2\delta ; \quad \text{or,} \quad x_1 = \frac{h}{\tan 2\delta} = \frac{h (1 - \tan^2 \phi)}{2 \tan \phi} .$$

If $\delta = -(90° - \phi)$, the Sun appears only on the horizon due south. In this case, eq. (6), on account of its form, fails to reveal the character of the parabola, but if the given condition be introduced into eq. (13),

$$x_1 = \frac{h}{0}\,[\tan\phi - \sec^2\phi \cos(\phi - 90°) \sin(\phi - 90°)]$$

$$= \frac{2h\tan\phi}{0} = \infty.$$

In other words, when the Sun is seen only on the horizon due south, the shadow of the bead, that is, the vertex of the parabola, is infinitely distant.

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SOME OF THE RESULTS OF ASTRONOMICAL PHOTOGRAPHY PERTAINING SPECIALLY TO THE WORK WITH A PORTRAIT LENS.*

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In the present paper I wish to offer a few specimens of astronomical photographs which have been made with portrait lenses. These pictures, which are from my own work, are fair samples of what can be done with this class of lens. They have been selected to show the variety and extent of the work, which covers the Milky Way, the nebulæ, the larger star clusters, meteors, comets, the earthlit and the totally eclipsed Moon, etc. Most of the pictures were made with the 10-inch Brashear lens of the Bruce telescope of the Yerkes Observatory.

The Advantages of Photography in Astronomy.

Before the application of photography to the study of the heavens, one saw the sky but poorly indeed, and in the light of the revelations of the photographic plate today, one is almost tempted to say that he did not see the heavens at all, so vastly has photography enlightened us as to the actual appearance of the sky and its citizens.

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There are two causes that have helped to produce this wonderful power that photography has given us. First, above all, the great sensitiveness of the photographic plate over that of the human eye. Second, the fact that our plates show us a vastly larger space of the heavens than the visual telescope does—in some cases a thousand times greater than is shown by our most powerful telescopes of today. A wide field of view is of the utmost importance in the study of the tails of comets, of the larger nebulæ and of the cloud forms and structure of the Milky Way, for these in general are very large. The field of view of a visual telescope, which is at most but a mere speck of the sky, is entirely too small to take in the whole of such an object. In the case of the Milky Way, the structural details are on such a grand scale that their true forms could not even be guessed at with the ordinary telescope. The importance, therefore, of the large field that the photographic plate gives us is very evident.

But there is one thing which we must take into account. The time element enters strongly into the photographic part. One may look into a telescope and he will see at once, if the conditions are favorable, the faint star or faint nebula he has in the field of view—it is but a moment that the eye takes to fix the image before it. Perhaps some very faint and difficult object may require a little longer, but it is only because a special moment of steadiness is waited for. The photographic telescope with its highly sensitive plate will not catch the object in that same time. It may require an hour or more before it "sees" it. But with the eye there is no cumulative effect; on the contrary, indeed, it soon becomes tired, so that in a sense, the longer you look the less you see, merely from the fatigue of the eye. With the plate there is no fatigue. The longer it looks the more it sees, so, though it may take it an hour to see what the eye readily perceives in a moment, it does not stop at that point but goes on seeing more yet, the longer it looks. In this way it soon registers things that the eye cannot perceive at all with equal optical means, and in many cases it reveals objects—especially among the nebulæ—that the eye may never see in the actual sky. And, what is of immense advantage, it permanently records what it sees, so that the exact appearance of a nebula may be preserved for future reference perhaps hundreds of years hence, while the view obtained by the eye is as evanescent as the fleeting glimpse of the object itself. Even though the observer should

make a careful drawing it is too often worthless, and misleading, for reference with other drawings, made later on; for the astronomer is seldom or never an artist.

If one examines drawings of the same celestial object by different observers, he is often struck with the want of agreement in these pictures. There are a few of the more prominent nebulæ such as the celebrated ones of Orion and Andromeda, which have been drawn by many observers. There is a strange want of resemblance among these pictures, and what is worse still there is often but little resemblance to the object itself. There was always the possible excuse that the object had actually changed its appearance in the sky. Photography, however, in the past twenty years has shown that such appreciable changes have not really occurred, though they must occur in the course of time.

The best illustration of this want of harmony in different delineations of the same astronomical subject is shown in the large number of drawings of the solar corona made by numerous observers at the total eclipse of the Sun in 1878 which were collected and published by the United States government. No two of the forty odd drawings closely resembled each other and few of them looked at all like the indifferent photographs obtained at the time. Indeed these drawings and other similar ones led an eminent astronomer four years later to declare that the corona was not a real phenomenon belonging to the Sun, but that it was partly a diffraction effect and partly in the eye of the observer, so that each observer, as it were, saw a different phenomenon—an idea that no one would think of holding today when photography has long since clearly demonstrated the solar origin of the corona.

The real cause of these various discrepancies lay mainly in the want of artistic skill in the observer, who saw the things all right but was unable to draw them correctly, especially was this so in the case of an eclipse of the Sun, where the excitement of the moment was enough to unnerve most observers.

Perhaps the greatest sufferer from this want of pictorial skill was the occasional comet. These bodies are really subject to remarkable and rapid changes and hence a misrepresentation was all the more unfortunate. In the case of the nebulæ one could simply throw out the poor representations as being due to lack of skill. In the case of the comet no one can tell whether the want of agreement in the various drawings was not due to actual changes in the comet itself. Happily today,

the lack of artistic skill in the individual plays almost no part in astronomical work. The photographic plate, not only with an accuracy far beyond that of the most skillful artist but with an eye almost infinitely more sensitive, sees the faintest details of a comet or a nebula and records them with a faithfulness unheard of before.

Today the sensitive plate is not only taking the place of the astronomical draughtsman, but it is also running the most skillful measurer a close race. The facility and ease with which great numbers of star places can be measured on the photographic plate, commend it to the most exacting astronomer.

Photography has materially altered our ideas of the nebular theory. From the views of the nebulæ with telescopes not sufficiently powerful to properly deal with them, and hence with views that were more or less erroneous, a theory was elaborated that appealed to the popular mind with a wonderful fascination. There is much that must be changed in this theory to meet the rigid requirements of modern science and to satisfy the demands of what has been revealed in the forms of the nebulæ by the photographic plate.

It is in dealing with the nebulæ that astronomical photography has attained one of its most remarkable triumphs. These bodies in reality shine with a light that has comparatively little effect on the human eye but to which the photographic plate is singularly sensitive. To our eyes the nebulæ are seen "through a glass darkly," as it were, while to the eye of the sensitive plate they are more or less brilliant objects.

Our old ideas of the dimensions of these vast bodies have also been greatly changed. In the days of purely visual astronomy, the great nebula of Orion, covering as it does some half a degree of the sky, was looked upon as inconceivably great in actual extent in space—yet photography has not only increased its extent very greatly, but it has revealed other nebulæ, unknown to us before, that are hundreds of times vaster than this great nebula of Orion. The Pleiades are in the midst of a mighty system of nebulosity that covers at least one hundred square degrees of the sky, and whose actual extent in space almost defies calculation.

Four or five degrees north of the star Antares, in the Scorpion, is a faint star just fairly visible to the naked eye.

This is known as Rho Ophiuchi. If one examines the space about this star with a telescope he sees nothing remarkable except that there are fewer small stars in this region—yet photography shows us that the sky here is covered by an enormous and magnificent nebula which apparently lies in a hole in the sky. From this great vacant region—vacant in the sense of there being few or no stars in it—narrow dark lanes run eastward for many degrees. But the singular thing is that the nebula seems in some way to be responsible for the absence of stars at this point. Whether this is due to the obscuration of the light of the small stars, that ought to be here, by the nebula, which would in that case prove it to be nearer to us than the stars, or whether the presence of the nebula has in some way destroyed or dispersed the stars cannot be told.

Perhaps the most extraordinary revelations of photography in astronomy have been in the case of comets. These wonderful objects with their vast trains sweeping through space are singularly subject to disturbances by other celestial bodies. The photographic plate has shown us that the comets utterly transform themselves in a few hours' time, for, though of vast dimensions, they are in reality but flimsy affairs with little or no solidity. In these changes, so faithfully recorded by photography, they sometimes, through the distortions of their trains, reveal the presence of some kind of resisting medium or of some unknown bodies through whose attraction, or by collision with which their tails are twisted, broken or deformed in the most extraordinary manner. This was the case with one of the comets of 1893 where photographs on successive nights show the tail disrupted and broken, undoubtedly by such an encounter. What this really means we have yet to learn. Possibly the comet passed through a dense swarm of meteoric bodies in its flight around the Sun. Photographs of another comet showed the tail entirely separated from the head and drifting away in space. From these last pictures it was shown that the particles forming the tail were leaving the comet with a velocity of twenty-nine miles a second.

Importance of the Portrait Lens.

The strangest thing in connection with these statements is that the greater portion of these photographic revelations have been made with instruments that are extremely crude

in comparison with the elaborate and expensive telescopes with which our great observatories are equipped today. Indeed in many cases the lenses were not made for the purpose to which they have been put. It was only incidentally that their services came to be of benefit to astronomy. I have often thought of the strange difference in the present use of these lenses and the one for which they were originally made. Though it would be hardly fair to attribute their origin to the purpose of human vanity, it was certainly vanity that had much to do with it, for these large lenses were made purely for the taking of portraits. In the days of the wet plate process the slowness of the sensitive agent used in the plates made it necessary to employ very large lenses so as to collect a greater quantity of light, and thus to shorten the time of the sittings. Their use has therefore not fallen to a lower level in this change but has risen to a much higher one —from the picturing of human vanity in the human face to the picturing of the sublime features of the face of the heavens. Their great light grasping power is no longer needed for the enlightenment of human vanity—not that that evil has in any way become extinct—but from the fact that with the extremely rapid dry plates of today the work can be done with very much smaller and less expensive lenses.

Description of Plates.

Nebulæ and Nebulosities.

For an example of nebular photography with a portrait lens perhaps one of the best specimens is that of Plate I* (exposure 4 hours), which shows the "North America Nebula." Though this plate does not represent all that is visible on the original negative, it yet shows how beautiful the nebula is, and how appropriate was Dr. Max Wolf's naming of it. The nebula is not a faint object with a telescope—indeed it was discovered over a hundred years ago by Sir William Herschel. It is not, however, suited for visual observations. With a small telescope one sees only a diffusion of feeble light which has no definite form or limits. It is, nevertheless, excellently and specially adapted for photographic representation because of the peculiarity of its light, which is very rich in photographic qualities. A long exposure, however, is required to show the fainter outlying masses of nebulosity which are clearly shown in the present picture. This photograph was made with the 10-inch Bruce portrait lens of the Yerkes Ob-

* This plate has been omitted because it is too large for insertion in Popular Astronomy.

servatory in the splendid atmosphere of Mount Wilson, California, where the writer had taken it in 1905, through the courtesy of Professor Hale, for the photographing of the Milky Way.

This picture exemplifies in a striking manner a peculiarity which is often found in connection with these large nebulosities and to which I have frequently called attention. That is the apparently free mixture of stars and nebulosity without any evidence of condensation of the nebulosity about the stars. I do not think this is necessarily a case of accidental projection of the stars and nebulosity, for there are numerous similar cases in the sky. In the present case one can trace out a similarity of configuration of the outlines of the nebula and the massing of the stars, which would strengthen the idea that they are at the same distance from us. This fine object is in the Milky Way a short distance east of Alpha Cygni, which star is shown at the western edge of the plate.

A good example of the fainter and more difficult nebulosities is shown in Plate XVII, the nebulous region of Gamma Cygni (exposure 6 hours 30 minutes). These nebulosities are not visible with the telescope because of their exceeding faintness. Their full extent is not shown in the photograph, for they extend considerably beyond the limits of the plate. It will be seen that Gamma Cygni, the star in the middle of the picture, is in a region of diffused nebulous matter which extends over a large area and is gathered in masses of greater brightness at different points, but is in general formless and diffused.

The lower picture of Plate XVII is a still finer example of the photographic nebulosities—*i.e.*, nebulosities that are too faint to be seen with the telescope and for the knowledge of which we are dependent on the photographic plate. This is the magnificent region of the great nebula of Rho Ophiuchi (exposure 4 hours 30 minutes). Unfortunately the reproduction is a failure, for much of the nebulosity and the great vacancies connected with it, that are so wonderfully shown in the original, are all but lost in this half-tone.

I think there is no other region in the entire sky so remarkable as this of which Rho Ophiuchi appears to be the center. The great nebula itself, which seems to cover almost this entire region with its extensions, and its association with the extraordinary star vacancy here are very puzzling, and lead one to believe that the apparent paucity of small stars at this point is due in some way to the presence of the nebula.

PLATE XV.

N

Double Cluster of Perseus
1904 September 15

N

Two Meteor Trails, and Star Cloud in Scutum
1904 April 20

Photographed with the Bruce telescope, Yerkes Observatory

PLATE XVI.

N

Meteor Trail
1899 June 7

N

Brooks' Comet and Meteor
1893 November 13

Photographed at the Yerkes and Lick Observatories

The great dark lane or rift running to the east, extends as far as the region of Theta Ophiuchi and seems to be a part of the system of vacancies that occur to the east and south of Theta.

The great nebula is full of remarkable details. There are a number of principal condensations, that of Rho Ophiuchi being perhaps the most striking. The nebula extends to, and involves, the bright naked-eye star Sigma Scorpii in a strong condensation full of details. In several wave-like masses it involves and reaches beyond Antares, one of the brightest stars in the sky. It seems to faintly cover a great part of the sky here, extending so far north, perhaps, as to connect with the remarkable nebula about Nu Scorpii. There are traces of it extending as far south as Tau Scorpii.

Perhaps as remarkable as any thing in connection with this nebula is the fact that it is so faint that the eye, armed with the most powerful telescope, cannot see it. Its light seems to be almost entirely photographic, and though too faint to be seen in the telescope it is doubtless very bright to the photographic plate.

At the lower part of this plate, a half inch to the left of the small cluster (M 4), is apparently an ordinary star. This is the bright red star Antares which is the brightest in this region of the sky, but which, from its red color, appears quite small and insignificant on the photograph. A half inch above the cluster is the star Sigma Scorpii which is much less than Antares. Sigma Scorpii is the center of a bright condensation of the nebulosity which in the original is seen to connect with the larger nebulosity (in the middle of the plate) about the star Rho Ophiuchi. The dark lanes running from the nebula east, though strong and conspicuous in the original, are nearly lost in the reproduction.

The first picture in Plate XV is a photograph of the region of the double cluster of Perseus (exposure 5 hours 55 minutes), which gives a good idea of the gradual massing of the stars from a region of uniform distribution into two clusters whose stars are brighter than the average of that part of the sky.

Meteors.

The unpredicted appearance of the occasional meteor, the suddenness with which it appears and the rapidity of its flight across the sky, make it impossible to locate its path with exactness by eye observations alone; though observers skilled

in this class of work can secure a close approximation to the path. If two such observers are separated by several miles, a fair idea may be obtained of the distance of the meteor and of its actual path through our atmosphere. In general, however, there is always much uncertainty attached to such results. What one really sees is a more or less bright point of light darting suddenly across the sky—the duration of whose flight seldom exceeds one second of time and the image of which vanishes from the brain almost as soon as it is formed. It may well be imagined how difficult is the exact location of the path of this fleeting point among the stars. If the meteor could have left a line of light on the sky along the full extent of its course for a few minutes, then one could locate its position fairly with respect to the stars, and yet this would still have considerable uncertainty attached to it from the fact that at best only an estimate (and no measures) could be made with the naked eye of the position.

In photographing the sky with wide angle lenses it is not an uncommon thing for a meteor to take its flight across the region which is being photographed. In this case when it is bright enough, the meteor actually does leave a permanent path among the stars; for the moving point of light affects the sensitive plate, continuously, marking out thus a "trail" among the star images, which is permanent and whose position can be measured with very great accuracy.

If a second camera, some distance from the first one, is also photographing the same part of the sky the meteor trail will be recorded by both cameras and its displacement on the two plates as photographed from these two points on the Earth, can be determined accurately and the distance and path of the meteor will become known. Such an instance occurred at the Yerkes Observatory where the same meteor was photographed with two cameras (by Mr. Frank Sullivan and the writer) separated by 400 feet only. The parallax or displacement of the trail among the stars was clearly shown. Measures of these two plates show that the meteor was about 90 miles above the Earth's surface.

In Plates XV and XVI are given specimens of meteor photographs selected from a great number of such plates. The lower photograph of Plate XV (region of M 11, exposure 2 hours 40 minutes), shows the trails of two meteors which were nearly in a straight line, so that, at first thought, one would suppose it was the trail of one meteor which had been

PLATE XVII.

N

Nebulous Region of Gamma Cygni
1905 August 28

N

Nebulous Region of Rho Ophiuchi
1905 April 5

Photographed with the Bruce telescope, Yerkes Observatory

PLATE XVIII.

N

Giacobini's Comet
1905 December 29

N

Giacobini's Comet
1906 January 5

Photographed with the Bruce telescope, Yerkes Observatory

interrupted near the middle of its flight. Both meteors were moving toward the south, it is assumed (for they were not seen by the observer), and were undoubtedly Lyrids—having a radiant in the constellation of Lyra.

Plate XVI (α 17 hours 20 minutes, δ south 15°; exposure 1 hour 34 minutes) shows in the first case the full flight of a meteor which evidently exploded near the end of its path, as indicated by that portion of the train which is of greater brightness. The lower photograph shows a great meteor trail and Brook's comet, IV, 1893 (exposure 2 hours 5 minutes). The bright trail was caused by a very large meteor which was seen by the observer. It was moving toward the southeast and exploded just off the edge of the plate. By one who is regularly photographing the sky with these rapid lenses, meteors are thus frequently caught in their flight.

Comets.

Plate XVIII shows two views of Giacobini's comet (c 1905). The first of these (December 29, exposure 1 hour 38 minutes) is the most interesting because of the peculiar form of the tail of the comet. The edges of the tail are convex and sharply defined, and they taper to a narrow neck where they join the head, which is quite large. The tail was doubtless a hollow cone. There is a narrow hazy strip running from the lower or south edge of the tail near the middle of the plate. In the original this can be traced across the edge of the tail onto the tail itself. On the next night December 30, all this definiteness of form had disappeared and the tail was very wide and diffused.

The lower plate (exposure 1 hour) is very interesting, but the main features of the tail are lost in the reproduction. Both photographs have suffered greatly in making the half-tones.

The Lunar Surface under Various Kinds of Light.

Plate XIX shows two photographs of the Moon. The size of the lunar image on photographs with a portrait lens (a half inch in diameter with the 10-inch telescope) is too small to be of any importance in the study of its crater and mountain-scarred surface. Such photographs, ordinarily, are, therefore, not worth the making. But there are conditions under which the Moon may be photographed to advantage with these lenses—not for a study of the craters and mountains however. The first of these pictures (enlarged) shows the new Moon with the slender sunlit crescent embracing the dark or night

part, where no direct sunlight reaches the surface, or in other words it is the "old Moon in the new Moon's arms," which sometimes forms such a beautiful picture in the western sky at the vanishing of twilight when the Moon is but a few days old. With the exception of the bright crescent, what we see is the lunar night, but it is a full "Moon" night, for the illumination is entirely by sunlight reflected from the surface of the Earth onto the night side of the Moon. At that time if one were placed on this night part he would have seen the Earth shining in the night sky like a great round Moon (nearly full) some thirteen times bigger than the Moon ever appears to us. The distinctness with which the lunar surface is shown in the photograph (with only 20 seconds' exposure) gives an idea of how brilliant the full Earth must be when shining in the lunar night. This picture was made for comparison with the full Moon and with the totally eclipsed Moon, for the surface is then shown under three different kinds of illumination, *i. e.*, direct sunlight (full Moon), reflected sunlight (Earth lit Moon), and refracted sunlight (totally eclipsed Moon) to see if any difference could be detected in the appearance of the surface as affected by these various illuminations. Portrait lenses are specially suited for this purpose.

The second picture of this plate is a photograph of the totally eclipsed Moon (exposure 9 minutes) in which the only illumination is due to the sunlight refracted through the Earth's atmosphere and bent into the shadow of the Earth onto the Moon. One of the reasons for making this picture was a hope that if any small body should be attending the Moon in its journey around the Earth (a small satellite for instance) it might be outside the shadow at the time, and being thus illuminated by the Sun, would show on the photograph. The Moon itself is ordinarily so bright that it would drown out the light of any faint body that might attend it.

Both the photographs of Plate XIX are essentially ruined in the reproduction.

List of Lantern Slides.

This paper, when read, was illustrated by a number of lantern slides of the various photographs. A list of these is given below for completeness. I have arranged the slides in the order of subjects.

PLATE XIX.

N

Earth-lit New Moon
1907 February 14

N

Total Eclipse of the Moon
1906 February 8

Photographed with the Bruce telescope, Yerkes Observatory

I. *The Earth-lit and the Totally Eclipsed Moon.*

Slide 1.—The new Moon showing the lunar night, illuminated by the "full Earth."

Slide 2.—This is the totally eclipsed Moon illuminated only by refracted sunlight coming through the dense atmosphere near the Earth's surface.

II. *The Milky Way, Star Clusters and Nebulæ.*

Slide 4.—The great star clouds of Sagittarius, east of the Scorpion.

Slide 5.—The double cluster of Perseus.

Slide 6.—The nebulous region of Gamma Cygni.

Slide 7.—The "North America Nebula" in Cygnus.

Slide 8.—The nebulous region of Rho Ophiuchi.

Slide 9.—The nebulosities of the Pleiades. This shows well the remarkable thread-like strips of nebulosity, especially the one from Electra and the one near and parallel to it. The extent of the nebulosities is greater than usually shown in photographs of the cluster. The original negative shows the exterior nebulosities surrounding the cluster. Exposure 3 hours 40 minutes.

III. *Meteors.*

Slide 10.—This shows two large meteors which followed nearly the same path across the plate.

Slide 11.—This shows the full flight of a large meteor on 1899, June 7.

Slide 12.—These two pictures are of the same meteor, but with two cameras 400 feet apart. The small scale picture was made by Mr. Frank Sullivan with 3.4-inch portrait lens attached to the 40-inch telescope during Professor Frost's spectroscopic observations. The other was made with the 6-inch lens of the Bruce photographic doublet. An inspection of the trail with respect to stars near which the meteor passed shows a decided parallax. The distance of the meteor above the Earth's surface, from these two pictures, was about 90 miles.

IV. *Comets.*

Slide 13.—Swift's comet on 1892, April 7, showing a large mass and separate system of tails which were going out from the comet.

Slide 14.—Giacobini's comet, 1905, December 29. The picture shows the remarkable appearance of the tail, which on this date was quite unlike the tail of any other comet.

Slide 15.—Borrelly's comet on 1903, July 24. The second photograph on this slide was made by Mr. R. J. Wallace. The interval between the two pictures is 3 hours. The tail which was separated from the comet, had receded noticeably in three hours. Measures of the plates showed that the particles forming the tail were moving away from the comet at the rate of 29 miles a second. (See *Astrophysical Journal*, October, 1903.)

V. *Vacant Regions and Holes in the Heavens.*

Slide 16.—This is a remarkable region of vacancies in a great nebulous background in the constellation of Taurus (See *Astrophysical Journal* for 1907, April.)

Slide 18.—Vacant lanes running from the nebulous region of Rho Ophiuchi towards the east.

Slide 19.—Great vacant regions about the star Theta Ophiuchi, (See *Popular Astronomy*, No. 140.)

Yerkes Observatory, 1907.

FAITH AND THE FOURTH DIMENSION.*

HAROLD JACOBY,

Rutherfurd Professor of Astronomy.

Why should the astronomer come into this chapel of St. Paul to fill a few minutes out of your busy day with his spoken thought? Paul himself asks the question: "Doeth he it by the works of the law or by the hearing of faith?" What is the astronomer's answer to that question? Does he depend on the law alone?

There is a difficulty through which many young men pass, through which especially the ablest young men must often pass: it is the difficulty of holding fast to the faith. Can this great body of spiritual truth be real? The young man turns in his doubt to the realm of science, where stern logic holds sway, where dwell the truths that seem to admit of complete logical proof. But the whole range of science contains nothing more firmly founded on irrefragible reasoning than the simple

* Address delivered in St. Paul's Chapel, Columbia University, New York, at one of the daily services, March 9th, 1908.

propositions of elementary geometry. Perceptible dimly in the remotest haze of intellectual antiquity; codified first by the Greek; conned by the Arab in the days of Harun-al-Rashid; pondered in the cloistered cell of the monk of Spain; important product of the far-famed early press of Venice; advancing unchallenged through more than twenty centuries of the darkness, and of the twilight, and of the dawn:—Euclid, geometer of geometers, ὁ στοιχειωτής, maker of the very elements, where stands he now?

In the year 1830, Nikolai Lobachevsky, son of a Russian peasant, put forth his epoch-marking proof that the well-known propositions of elementary geometry are not necessarily true, that Euclid's demonstrations are not in accord with the extreme requirements of rigid logic. For instance, you all remember the well-known theorem of elementary geometry concerning the sum of three angles of a triangle. Lobachevsky built up and published a complete system of geometry in which this proposition does not occur, and in which this proposition is not true.

If we accept the principles of inductive science there is but one way to test the truth or falsity of this theorem of the angles. It is necessary to experiment, to make actual measurements upon an actual triangle. But real measurements can never be accurate absolutely. They all depend ultimately upon fallible human senses and more or less defective instruments made by fallible human hands. Slight errors of observation always occur; these render results uncertain; it is possible to prove by observation that the angle theorem is very nearly true, but not that it is *true*. It may even be that the divergence from truth might show itself in an increasing degree if it were possible to execute our measurements upon very large triangles. Even astronomy is limited to measurements made from the Earth: possibly, if we could go forth into the profound depths of space; if we could bridge the distance by which we are sundered from the stars; if we might even pass beyond the confines of the visible sky and push our mighty triangle to the very fringe of the invisible universe:—possibly then, and then only, could we make evident the truth.

Now this idea of Lobachevsky involves a revision of our notions concerning space: his idea can hold only in a space different from that we have inherited from Euclid. Lobachevsky's is space of four dimensions. For my present purpose it is not necessary to explain in detail or to understand fully

the mysterious fourth dimension. Regard it, if you will, as a mere figment of mathematical imagination: the fact remains that science today knows not, and cannot ascertain without impossible experimentation, whether Euclidean geometry is a truth.

But we all believe our geometry; none credit as real the half-ridiculous phenomena of an imaginary fourth dimension. Astronomers study the skies; physicists theorize in their laboratories; all believe in ordinary common-sense geometry. Therefore is it possible for science, like religion, to believe something not logically proven.

Science today has attained only to the portal of knowledge: when her forces shall have stormed the citadel, when she shall stand upon the deepest foundation stone of truth attainable by man, she will find, surely, that stone bedded upon some kind of faith, some belief outside the domain of rigid logic.

AN ASTRONOMICAL THEORY OF THE MOLECULE AND AN ELECTRONIC THEORY OF MATTER.

Solar and Terrestrial Physics Viewed in the Light Thereof.

SEVERINUS J. CORRIGAN.

Part III. (Continued.)

The Nature of the Solar Radiations and their Relation to Terrestrial Magnetism and Other Meteorological Phenomena.

For Popular Astronomy.

Experimental determinations of what is called the "solar constant," which is the quantity of heat radiated, in unit time, from unit surface of the Sun, and received, in the same time, upon unit surface at the Earth, have been made, in the quite recent past, by several skillful and eminent physicists—Pouillet, in France; Langley in the United States, and others—one of the latest results in this line of investigation being that announced by the distinguished German astrophysicist, Scheiner, in his book treating of solar radiation and the temperature of the Sun, published at Leipzig in 1899, A. D.

According to Dr. Scheiner, the quantity of heat, measured in thermal units, (the unit here taken being the pound-degree Fahrenheit; i.e., one pound of water raised through one de-

gree of the Fahrenheit scale) received, per second, upon one square foot placed at a right-angle to the solar rays, just outside the Earth's atmospheric envelope, is between one-fifth and one-quarter of a unit, the corresponding values of the radiation from one square foot at the Sun's surface being equal to the product of the aforesaid quantities by 46,200 which is the square of the mean distance of the Sun from the Earth, measured in terms of the radius of the solar globe, which radius is taken as 1, the resulting limiting values of the "rate of radiation" at the Sun's surface being, therefore, 9,240 *TU* and 10,780 *TU* respectively.

The former of these two values is in closer agreement with other determinations than is the latter, it being not far from a "mean" of all the most reliable measurements, and it will, therefore, be taken, in this connection, as representing, with all needful accuracy, the actual mean thermal radiation, per second, from one square foot of the Sun's surface, the difference between this and the several other determinations being largely due, simply, to variance between the estimates of the percentage of terrestrial atmospheric absorption of the solar thermal radiations.

The quantity of heat generated by the perfect combustion of one pound of *carbon* is, approximately, 14,500 thermal units, so that the heat-energy radiated, per second, from one square foot of the solar surface matter is equivalent to that developed by the complete combustion of nearly three-fifths of a pound, avoirdupois, of the best coal, in the same time, and as there are nearly 66 quintillions of square feet in the whole surface of the Sun, it follows that, *if each and every square-foot of said surface radiates the same quantity of heat*, the total thermal emission from the Sun is equal to that which would result from the perfect combustion of 20 quadrillions of tons of coal, per second, and the question as to the source of supply, and the final disposition, of so enormous a quantity of thermal-energy has long been—as it now is—a most interesting one, much mooted among physicists and others who have studied solar phenomena.

The great German physicist, Helmholtz, about 50 years ago, was probably the first one to definitely assign, as the source of supply of this enormous quantity of thermal radiation, the slow contraction of the gaseous mass which constitutes the Sun, and working upon the assumption that the solar matter is of *uniform density* throughout its volume, and undergoing

condensation *from infinite distance* under the action of its inherent force of gravity, he demonstrated that a contraction amounting to only one ten-thousandth part of the diameter of the Sun would suffice to generate as much heat as would, at the present rate of radiation, be emitted by that body in 2,100 years, the rate of contraction of the solar diameter being, in this case, about 4.1 miles in one hundred years; but more recent determinations, based upon Helmholtz's principle, and employing later and more accurate values of the "rate of radiation," give nearly 9¼ miles, per century, or 16 inches per day, as the rate of contraction requisite for the maintenance of the present output of solar heat.

According to the principles of my theory, in this connection —as set forth in the February number of POPULAR ASTRONOMY —the contraction of the Sun's volume, under the action of gravity, whereby the solar heat has been generated and is maintained, is considered as a case of gaseous compression governed by certain laws of "thermodynamics," and as beginning when the radius of the volume of the condensing nebulous mass was so extended that the gaseous matter was in equilibrium, as to density, pressure and temperature, with the luminiferous ether, which condition involves compression from only a *finite and comparatively small distance*, and not as a contraction from *infinite distance* as under the concept of Helmholtz above stated, yet, notwithstanding this, and other, material differences between the concepts of the two theories in this connection, the present rate of contraction of the Sun's diameter, according to my determination is 9.28 miles, per century, a value substantially identical with that derived, as above stated, from the most recent investigation founded upon the aforesaid "principle" of Helmholtz—a remarkable coincidence which is not at all *fortuitous*, it being due to a certain relation between the density and pressure of the ether, the centripetal force of gravity, and the antagonistic centrifugal force of radiation one consequence whereof is what has been termed the "pressure of light"—all of which relations are rigorously explicable by my theory of radiation and of the constitution of the transmitting medium, the ether.

The aforesaid deductions from the experimentally determined value of the *solar constant*, are all based upon the postulate that the thermal emissivity of the solar surface matter is the same over the whole area of the Sun, which is the idea generally held: but there is no positive proof whatever, that

each, and every, square foot of the Sun's surface is emitting thermal radiations uniformly at the rate indicated by the pyrheliometrically determined value of the *solar constant*, while there are certain facts of observation that lead directly to an opposite conclusion.

I shall now endeavor to demonstrate that, under the concepts of my theory as to the constitution of the transmitting medium which is known as the "luminiferous ether," and of the *modus operandi* in the propagation of radiant energy thereby, *the "rate of radiation" of the Sun's heat is variable with respect to heliographic latitude and longitude*, and that the area of maximum thermal emission is continually shifting relatively to these coördinates, and I shall adduce testimony, based upon well-observed phenomena of solar physics, in behalf of my claim that the planetary bodies of the solar system, which are continually changing their positions relative to any given heliographic latitude and longitude, are the prime—if not the sole—factors operating in the causation of certain peculiar and variable phenomena frequently observed upon the visible portion of the Sun's surface. To physicists, the assertion that any material surface cannot radiate heat and experience a consequent fall of temperature unless there be another material surface, or matter, at a lower temperature, somewhere in the lines of propagation, or the "rays," to serve as a receiver, or "absorber" of the energy radiated (which is equivalent to a statement that the matter of the transmitting medium, itself, cannot act as such an "absorber") may seem a *bold* one and not susceptible of verification, or one even negatived by terrestrial experience in respect to "radiation" because we have no experience of a body, heated above the temperature of its surroundings, retaining, absolutely unimpaired, its temperature unless an adequate supply of heat be furnished it from some source of thermal energy.

But it should be noted that, in all cases of radiation upon the Earth, each radiating surface is surrounded by material surfaces that serve as absorbers of the emitted radiance, and that not even the resources of the best equipped laboratory, in the hands of the most skilful experimenter, can remove the radiating body from this hampering environment, and it is only when from the vantage ground of the astronomical and astrophysical observatory, the actions and reactions continually in operation upon the surface of the Sun, that greatest of laboratories, viewed from the standpoint of either the chem-

ist or the physicist are observed, and subjected to analysis, that the true state of the case, in this connection, is revealed. The Sun, completely enveloped by the matter of the all-pervading luminiferous ether which is well-nigh infinitely extended, is continually sending, in straight lines, through this medium, its thermal, and other, radiations outward into space even to the distance of the most remote star, these radiations being propagated with the velocity of light and with an intensity decreasing as the square of the distance from the solar surface, but the only portion of this enormous output of thermal energy from the Sun, of which we have actual cognizance, is the *modicum* of heat received upon one-half the Earth's surface, as measured by the portion falling upon the very small area of a pyrheliometric instrument.

The fixed stars, numerous and large as they are, lie at such enormous distances from the Sun that their absorptive effect upon solar radiation may be regarded as practically *nil*, and moreover, their surface temperatures are quite as high as—if not greater than—that of the Sun, so that according to the "principle of exchanges," each returns an equivalent thermal radiation to the latter body, the thermal emissivity thereof being consequently unaffected, in any sensible degree, by the stars, so that we may reasonably conclude that it is only the matter of the solar system—planetary and other—which is at an adequately lower surface temperature and sufficiently proximate to the solar globe, that can act as absorbers of the Sun's radiations, and it will now be demonstrated that the only significant factors, in this regard, are the Earth and the other seven known planets.

According to my hypothesis in this connection, solar thermal radiation can be emitted uniformly at the known rate indicated by the *solar constant*, only when the sum of what may be termed the "effective areas" of the planets, reduced to the solar surface, is equivalent to said surface, such a combination of areas presented normally to the rays of the Sun, and therefore parallel to the surface of that body being comparable to the concave surface of a spherical shell contiguous to, and completely enveloping, the solar globe, and acting as an absorber of the thermal energy emitted from the surface of the Sun; but if—as is the case—the sum of the *effective areas* is *less* than the whole surface of the Sun, the actual thermal radiation will be likewise *less* than that which would be emitted from the whole surface, its measure being the ratio

between the total *effective area* and the total solar surface.

The whole area of the Earth relative to that of the Sun is, obviously, proportional to the square of the ratio between the mean diameters of these two bodies and as this diameter of the Earth is 7912.4 miles and that of the Sun 864,340 miles the ratio is $\frac{7912.4}{864,340} = 0{,}009154$ the square of which, or the number 0.0000838, is the area of the whole surface of the Earth relative to that of the Sun. But the solar heat that falls upon any planetary body is emitted from only one-half the Sun's surface and is received, in unit time, by only one hemisphere of the planet, and for these two reasons, alone, the *effective area* is only one-fourth of that just stated; moreover, the radiations leaving the Sun do not all come to the Earth, in parallel lines, from a surface normal to the rays, but are inclined at divers angles, those emitted near the Sun's limb, obviously, passing through a greater thickness of solar atmosphere, or absorbing vapors, than those emitted from the central portions of the solar disk, by reason of which fact the *effective area* is further reduced by one-third, so that one-sixth of the relative geometric area aforesaid,—which is 0.0000840—represents the real *effective area* of solar radiation, in so far as the Earth alone is considered, and this will be designated by E its value being 0.0000140 of the whole area of the Sun. The value of E for any other planet is determinable through the equation; $E = 0.0000140 \left(\frac{\rho}{a}\right)^2$; in which ρ represents the mean diameter of the planet, relative to that of the Earth, and a the relative mean-distance from the Sun, in terms of the Earth's mean distance which is taken as 1, and through this equation I have derived the values of E for the eight known planets of the solar system, which are set forth in the following table:

TABLE A

Planet	Mean Diameter (Miles)	ρ	a	E	Percentage of ΣE
Mercury	3,000	0.3791	0.39	0.0000132	11.
Venus	7,500	0.9483	0.72	0.0000242	20
Earth	7,912	1.0000	1.00	0.0000140	11.½
Mars	5,000	0.6407	1.52	0.0000025	2
Jupiter	81,500	10.3031	5.20	0.0000549	45
Saturn	71,000	8.9732	9.54	0.0000124	9¾
Uranus	29,900	3.7789	19.18	0.0000005	0.½
Neptune	37,200	4.7025	30.07	0.0000003	0.¼
			Σ	0.0001220	100

The *effective area* of the Sun, with respect to thermal radiation, is equal to the whole geometric area which contains 6543×10^{16} square feet multiplied by the factor ΣE, which is 0.0001220, as set forth in Table A, the product being 7983×10^{12} square feet, and since the rate of radiation at the Sun's surface, experimentally determined as above stated, is 9,240 thermal units per square foot, per second, the whole mean *effective* radiation from the Sun is 7376×10^{16} thermal units, per second, or only the $\frac{1}{8200}$ th part of that which would be emitted were the emissivity of all parts of the solar surface the same, which is the commonly held view.

The aforesaid quantity of thermal energy radiated by the Sun, per second, is that which would be developed by the complete combustion of $2\frac{3}{8}$ trillions of tons of the best coal in the same time, instead of 20 quadrillions of tons which is the quantity in the case of *equal* radiation from the whole surface of the Sun, and, therefore, all quantities similarly dependent upon the value of the solar area, that have been heretofore deduced under the commonly accepted hypothesis in this connection, should be reduced to the 8,200th part of the values generally given by writers on this subject, if my hypothesis be true—and I have reason to claim that it is, but even these greatly reduced quantities are so enormous that they almost surpass ordinary comprehension.

In the preceding part of this paper, in the March number of POPULAR ASTRONOMY, (pp. 157-159), I pointed out the fact that under the conditions of my theory in this connection the volume of the Sun is yet undergoing a heat-generating compression caused by the force of gravity, and that the compressive process will continue until the density of the solar mass will have risen from its present value, 1.4 to 2.66 which is, approximately, the density of the surface matter of the Earth, after which time gaseous compression and the consequent generation of heat will end, the Sun then entering upon an extremely prolonged course of persistent decadence, as to temperature, which will cause that body to cease its function as the dispenser of radiant-energy, and which will ultimately reduce it to much the same conditions, as to temperature density, etc., as those now prevalent in the case of the Earth. I also demonstrated therein that, under these conditions, the contraction of the Sun's volume will continue until its diameter is reduced to 0.8074 of its present length which is 864,340

miles and, therefore, this contraction will be through a distance of 166,480 miles, the maximum internal absolute temperature of the solar matter increasing during the process, from its present value of roundly, 13,400 degrees Fahrenheit to 15,800 degrees, and its corresponding surface, or *effective* radiating, temperature from 6,700 degrees to 7,900 degrees, the increase of 2,400 degrees in the internal temperature representing only one-third of the whole augmentation that would result if the compression were adiabatic, or under the condition that no heat were radiated, or otherwise abstracted from the condensing mass during the progress of the compressive action. The heat thus lost during the process is two-thirds of all that generated by the compression, the temperature-loss (Te) being, therefore, 4,800 degrees, and the whole quantity of heat (Tu) lost by the solar mass during the process of compression from the present density 1.4 up to 2.66, is determinable through the equation; $Tu = W.\ s.\ Tu$; in which W represents the weight of the Sun, which is 4351×10^{27} pounds, avoirdupois, the specific-heat (s) of the solar mass being 0.20 and the temperature-loss (Te), as aforesaid, 4,800 degrees, the value of Tu being therefore 4177×10^{30} thermal-units. It is obvious that the number of years required for the completion of this process of compression, and the attainment of the maximum temperature of the Sun, were the rate to remain constant at its present value during the process, must be equal to $\frac{Tu}{Q}$, the denominator Q representing the quantity of heat radiated, per annum, at the present rate of thermal emission, its value being determinable through the equation; $Q = t.''\ E.A.R$; in which t'' represents the number of seconds in a year of 365¼ days; A the *whole* area of the Sun, which is 6543×10^{16} square-feet; E the coefficient 0.0001220 for the reduction to the "effective area" as set forth in Table A, and R the present "rate of radiation," per square foot, per second, as deduced from the experimentally determined value of the *solar constant*, its value being as stated on a preceding page, 9,240 thermal units, the value of Q as determined through the equation last set forth being, therefore, 2328×10^{24} thermal units.

A division of the above stated value of Tu by this value of Q, gives as the result 1,794,500 which represents the number of years that must elapse before the Sun reaches the epoch of greatest compression and temperature, and since

the contraction of the solar diameter, in that time, is through a distance of 166,480 miles the present rate of contraction is 9¼ miles per century or sixteen inches per day which is just equal to this rate as derived from the "principle of Helmholtz," aforesaid.

The latter value has been derived under the *assumption* that the contraction of the solar volume has been from *infinite distance*, an assumption that may be regarded as not well founded, because, if the volume of the Sun be expanded to *infinity*, the density of the solar mass would fall correspondingly below the density of the luminiferous ether that fills all known space, which density fixes the limit of all gaseous expansion, according to a fundamental concept of my theory, the limiting density or that of the ether, being, according to my determination, $\frac{1}{1926 \times 10^{13}}$ (as stated in the February number of POPULAR ASTRONOMY) when referred to the normal density of the atmospheric gases, which I have taken as the standard in this case because, according to a fundamental concept of my theory, the nebulous matter whence the solar mass has been derived, and also the matter of the luminiferous ether is *gaseous*. Furthermore, Helmholtz *assumed* that radiation takes place uniformly from all portions of the Sun's surface, while my concept is that it is emitted from only the 8,200th part of the whole surface or, rather, in a quantity that is equivalent to the maximum radiation from that portion of the geometric area of the Sun. The rate of contraction if the former assumption were the correct one would be 8,200 times the value 9¼ miles, per century, which I have derived, and which is identical with that resulting from the application of "Helmholtz principle" under his assumptions, but at so great a rate the whole contraction, through 83,240 miles of the *radius* of the solar globe, would be completed in only 210 years, which is manifestly an utterly inadequate period in view of known facts derived from observation of the phenomena of solar physics. The agreement, aforesaid, between the two values of the rate of contraction—that of Helmholtz and the one that I have obtained, analytically, from the principles of my theory—resulting as it does from the peculiar physical relations stated in a preceding paragraph, constitutes strong proof of the truth of my hypothesis as to the "effective area," (E) of solar radiation as a function of the relative

planetary areas reduced to the Sun's surface, and also of my fundamental concept of the density of the luminiferous ether, relative to the normal density of atmospheric air, as marking the limit of expansion in the case of all gaseous matter, and as the initial density at which the gaseous nebulæ are developed from the matter of said ether the absolute temperature whereof is the fundamental temperature whence, by gaseous compression in the case of the primitive solar nebula, the present temperature of the Sun has been evolved.

During this process the *effective*, radiating temperature of the Sun's surface will be increased, as aforesaid, by 1,200 degrees and this augmentation will, obviously, have the effect of increasing the rate of radiation and, therefore, the rate of contraction of the solar volume so that the time required for the completion of the whole process and the attainment of the maximum temperature, will be *less* than 1,794,500 years, which would be the length of the period were solar radiation to progress uniformly at the present rate. By means of an algebraic expression for the "law of radiation" that I have analytically derived from the principle of my theory and which holds good for very high as well as very low temperature, of a radiating surface, I have found that the increase of surface temperature aforesaid will reduce the period required for the completion of the process of compression to—*roundly*—1,080,000 years, during which time the intensities of all the solar radiations, thermal, luminous and electrical will be increased to 164 times their present values, the terrestial magnetic force being augmented by the same ratio, as will also be all atmospheric disturbances, electrical and mechanical, that are due to solar action upon the tenuous matter of the upper atmosphere and productive of what are called "storms."

In fact, under the conditions of my hypothesis in this connection, the increase of the *effective* surface-temperature of the Sun which is now 6,700 Fahrenheit, *absolute*, (about the temperature of the voltaic arc), or at the point where dissociation of the component atoms of the spherical molecules of the atmospheric gases, and the disruption of these molecules—productive of electrical action—begins, may not appear in the form of *heat*, the increase of energy due to the rise of the temperature aforesaid, being expended in *electrical and mechanical work*, upon the atmosphere, in which case there may be no sensible increase in the value of the *solar constant*, such a condition

being the cause of the *constancy*. The aforesaid conclusion to which my theory inevitably leads is, of course, directly opposed to the view now held by many physicists who, basing their opinion upon the fact that the solar radiation is so enormous, regard the sun as a *waning* star whereas, under my hypothesis, all its energies are *waxing* and will continue to do so for not less than one million years from the present time. After the epoch of maximum compression and temperature, the solar energies will *begin to wane*, but, as determined through my formula for the "rate of radiation," a further period of 720 millions of years must elapse before they fall back to their present intensities, after which an additional but lesser time will be required to bring them to a point so low that the Earth will be rendered uninhabitable; so that we may reasonably conclude that there will be no *permanent loss* of solar energy, capable of seriously affecting the welfare of mankind, for, roundly, two million years to come. When we consider the fact that the history of the human race—taking it in the widest sense — is all included within a period of, probably, 10,000 years, and that the solar radiations upon which the welfare, and even the very existence of that race depend, will not be disastrously impaired (at least by reason of *fall* of solar temperature) for 200 times the length of that period, we may reasonably regard our globe as only entering upon an epoch wherein the physical conditions will be well adapted to the existence of the human race—at least in so far as these conditions are dependent upon the solar energies radiated to the Earth.

Finally, in this connection, it is demonstrable, through my algebraic expression for the "law of radiation," that after the epoch of maximum compression and temperature and the return of the present conditions of solar radiation, a vastly longer period, amounting to 6¼ quadrillions of years, must elapse before the Sun finally cools to the present temperature of the Earth and becomes a "dark star" of which, according to a very modern astrophysical concept there are some wandering through the depth of space like "derelicts," on the ocean, occasionally colliding with other stellar bodies, in which case a portion of the kinetic energy due to their motion, thus arrested, is converted into heat sufficient to render them again self-luminous—or even to restore them to their primitive gaseous condition—any such body appearing then as a Nova, or new star.

If we consider the absorptive effect due to any one planet—

the Earth for instance—upon thermal radiation from the visible hemisphere of the Sun, under the condition of my theory that it is only to the planetary matter that such radiation can be emitted in sensible quantity, it is obvious that the area of maximum radiation, or of *greatest cooling*, will be that corresponding to the projection of the planet's *effective* area upon the solar disk. When the Earth is in the plane of the solar equator, i. e.,—at the nodes of this plane with the ecliptic,—this projected area will be central upon the disk, and from this focal area the rate of thermal radiation will decrease, on all sides, down to the limb of the Sun, instead of being uniformly constant over the whole visible hemisphere of that luminary. Under this condition it is obvious that, for each planet, there are two limiting *heliographic latitudes*,—one north and the other south of the solar equator,—between which this projection of the effective area, or the region of greatest radiation and consequent cooling, must be situate, and these limiting latitudes (l') are determinable in the following manner. Taking 7° 06′ as the inclination of the solar equator, to the ecliptic, and 74° 18′ as the heliocentric longitude of the ascending-node of the former plane, upon the latter, and also the like inclinations and longitudes of nodes, of the seven other planets, relative to the ecliptic, and reducing all to the solar equator as the *fundamental plane*, by means of the well-known formulæ of Spherical Astronomy for such reduction, I have obtained the values of the inclination (i') and of the heliocentric longitude (Ω') of the ascending-node, set forth in Table B, the limiting heliographic latitudes (l') between which the projections of the effective planetary areas and, therefore, of the regions of *greatest cooling* are to be found, being determined through the following equation, $l' = a \cos i' \tan i'$; in which a represents the mean distance of each planet, from the Sun, relative to the Earth's mean-distance therefrom, the values of a being taken from Table A, and those of l' being set forth in the following table:

TABLE B

Planet	Ω'	i'	l'	Earth at 90° from Nodes
	°	°	°	
Mercury	97.6	13.0	5.0	March 28 and September 30
Venus	96.9	8.6	6.1	" 27 " October 1
Earth	74.3	7.1	7.1	" 5 " September 7
Mars	83.8	8.5	12.8	" 14 " " 18
Jupiter	244.3	7.4	33.8	February 23 " August 28
Saturn	237.9	8.4	54.3	" 17 " " 21
Uranus	79.9	7.3	67.7	March 10 " September 13
Neptune	241.4	6.1	72.3	February 20 " August 25

The theoretical results which I have thus derived and tabulated, as above, are, to say the least, *very suggestive* concerning some of the most remarkable, interesting and important phenomena of solar physics and I think that the concordance between my theoretical results and those of observation which is disclosed, cannot be attributed to any chance combination of figures—there are too many factors in the problem to admit of such a contingency. Under this theory, heat is of course, regarded as radiating, in some degree, from all parts of the Sun's surface, the internal matter, which is at an absolute temperature of 13,400 degrees Fahrenheit, according to my determination, rising upward to the surface as glowing (but relatively weakly-luminous,) gases which there part with a portion of their heat and fall to a temperature of 6,700 degrees which is the effective, radiating surface temperature and that at which highly heated carbon-vapor would be, by loss of heat, transformed into finely-divided, *incandescent solid* particles such as those of which the Sun's *photosphere* is most probably composed and which furnish the continuous part of the solar spectrum. The density of this cooler surface matter must be *double* that at which it was when in its more highly heated state, because the absolute temperature of the matter has been decreased, after reaching the surface, to *one-half* that which it possessed when in the interior of the solar globe, and becoming thus heavier, it must sink gradually, and in some cases fall rapidly back to the interior whence it arose in its hotter and lighter state, the whole process being one of *convection* due to difference of temperature and density between the internal and the surface matter, as it must be because, as is well-known, the "thermal conductivity" of gases is very low, and it is to these ascending convection-currents of highly heated but *weakly-luminous* gases, and to the descending streams of heavier and cooler but *highly incandescent* matter, that the "prominences," "jets", "spots," filaments and faculæ and the generally mottled appearance of the solar disk are due.

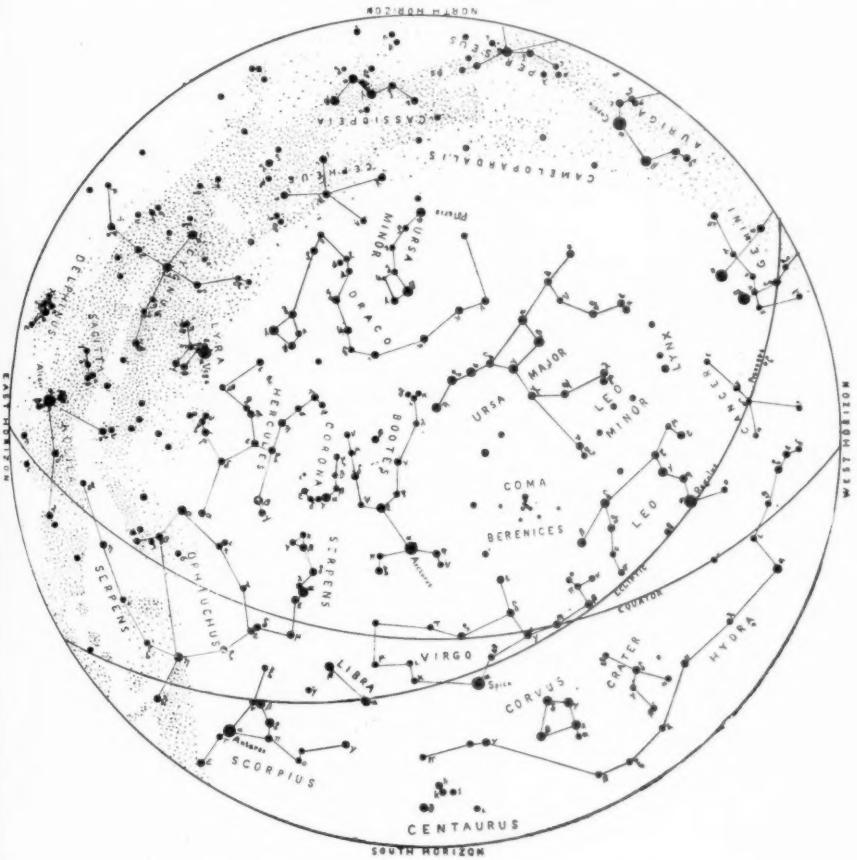
St. Paul, Minn.

To be continued.

PLANET NOTES FOR JUNE 1908.

H. C. WILSON.

Mercury will be at greatest elongation, east from the Sun 24° on the evening of June 7, and will be visible as evening star for a few days about that time. Its brilliancy, however, will be low at that time, so that



THE CONSTELLATIONS AT 9:00 P. M., JUNE 1, 1908.

it will not be very conspicuous to the naked eye. Mercury will be in conjunction with Mars on June 7 at 10 a. m., and with Neptune on June 10 at 10 p. m., Central Standard Time. At the former date Mercury will be only 19′, or about two-thirds of the Moon's apparent diameter, north of Mars

and on the latter Mercury will be 1° 37′ north of Neptune. Mercury will again be in conjunction with Neptune on June 30 at 10 p. m., being then 3° 17′ south of Neptune.

Venus begins the month as a very brilliant star in the west in the evening, but is now moving rapidly in between the Earth and Sun and so turning more and more of her dark side toward us. Her brilliancy will thus diminish in the ratio of 184 to 15 during the month, aside from the effect of the twilight glare. She will be at inferior conjunction on July 5. The phase of Venus is now crescent, diminishing from 0.25 on June 1 to 0.01 on June 30.

Mars will be in conjunction with Venus June 22 at 2 p. m., but Mars will then be on the farther side of his orbit from the Earth while Venus will be on the nearer side of hers so that the contrast between the two will be extreme.

Mars will be in conjunction with Neptune on June 12 at 4 a. m., Mars being then 1° 53′ north of Neptune.

Jupiter is past its best position for this year but is still brilliant in the western sky in the early evening.

Saturn is to be observed in the morning, toward the southeast, coming to quadrature, 90° west from the Sun July 1.

Uranus is nearing opposition, and may be studied after midnight on any clear night. It is in the constellation Sagittarius.

Neptune is too close to the Sun for observation in June.

Occultations visible at Washington.

Date 1908	Star's Name	Magnitude.	IMMERSION. Washington M.T. h m	IMMERSION. Angle from N. °	EMERSION. Washington M.T. h m	EMERSION. Angle from N °	Duration. h m
June 9	80 Virginis	5.6	10 59	113	12 12	304	1 13
11	o^2 Libræ	6.2	13 46	116	14 52	277	1 06
13	Bradley 2162	6.3	7 48	54	8 25	346	0 37
14	Bradley 2276	5.2	9 11	72	10 11	314	1 00
15	B A.C. 6576	6.1	9 00	119	9 59	254	0 59
15	χ Sagittarii	5.5	14 04	55	15 14	291	1 10
16	Piazzi xx, 146	6.2	13 51	61	15 07	274	1 16

Phenomena of Jupiter's Satellites.

Central Standard Time, beginning at noon.

	h	m					h	m			
June 2	7	32	I	Tr.	In.	June 13	7	39	III	Tr.	Eg.
	8	03	IV	Oc.	Dis.		7	51	III	Sh.	In.
	8	38	I	Sh.	In.	17	8	49	I	Oc.	Dis.
	9	25	III	Oc.	Dis.	18	8	21	II	Tr.	Eg.
	9	53	I	Tr.	Eg.		8	24	II	Tr.	In.
3	8	12	I	Ec.	Re.		9	16	I	Sh.	Eg.
4	7	56	II	Sh.	Eg.	20	7	31	II	Ec.	Re.
6	7	34	III	Sh.	Eg.		8	16	III	Tr.	In.
9	8	18	IV	Oc.	Dis.	25	8	1	I	Tr.	In.
11	7	21	I	Sh.	Eg.	26	8	26	I	Ec.	Re.
	7	38	II	Sh.	In		9	12	IV	Oc.	Re.
	8	33	II	Tr.	Eg.						

Note.—In., denotes ingress; Eg., denotes egress; Dis., disappearance; Re., reappearance; Ec., eclipse; Oc., occultation; Tr., Transit of the Satellite: Sh., transit of the shadow.

COMET NOTES.

Ephemeris of Encke's Comet.

[For Berlin noon; from *Astronomische Nachrichten* 4241]

1908	α app. h m s	δ app. ° ′	log r	log Δ	Aber. Time m s
May 26	3 2 7	— 5 39.7	9.8483	9.6129	3 25
27	2 57 24	7 2.1	8593	6021	19
28	52 33	8 25.3	8702	5920	15
29	47 35	9 49.1	8806	5829	11
30	42 29	11 13.8	8908	5739	7
31	37 16	12 39.3	9007	5659	4
June 1	31 54	14 4.3	9108	5484	3 0
2	26 24	15 30.3	9196	5515	2 58
3	20 44	16 56.9	9287	5451	55
4	14 56	18 23.7	9376	5394	53
5	8 57	19 50.6	9462	5343	51
6	2 2 47	21 18.1	9546	5295	49
7	1 56 24	22 45.7	9627	5248	48
8	49 49	24 13.2	9707	5210	46
9	42 58	25 40.5	9786	5177	45
10	35 54	27 8.5	9862	5151	44
11	28 33	28 34.0	9.9936	5130	43
12	20 58	29 59.7	0.0008	5111	42
13	13 5	31 24.6	0078	5097	41
14	1 4 57	32 47.9	0148	5088	40
15	0 56 32	34 9.0	0216	5083	40
16	47 50	35 27.9	0282	5083	40
17	38 52	36 45.2	0348	5091	41
18	29 34	37 59.3	0414	5105	41
19	19 58	39 10.9	0473	5123	42
20	0 10 4	40 19.8	0532	5147	43
21	23 59 54	41 25.0	0593	5176	44
22	49 31	42 24 0	0651	5210	45
23	38 54	43 18.5	0708	5250	47
24	28 6	44 9.3	0765	5295	49
25	17 10	44 55.7	0820	5345	51
26	23 6 7	45 36.2	0875	5401	53
27	22 55 0	46 13.2	0927	5460	55
28	43 52	46 44.7	0978	5524	2 58
29	32 46	47 11.4	1030	5594	3 1
30	21 45	47 32.8	1080	5668	4
July 1	10 53	47 50 0	1129	5742	7
2	22 0 15	48 2.5	1178	5826	11
3	21 49 48	48 10.8	1226	5910	14
4	39 36	48 14.5	1273	5997	18
5	29 42	48 14.5	1319	6087	22
6	20 12	48 11.4	1364	6178	27
7	11 4	48 5.3	1488	6272	31
8	21 2 17	47 56.1	1452	6368	36
9	20 53 53	47 44.1	1495	6466	41
10	45 52	47 30.1	1537	6564	46
11	38 12	47 14.4	1580	6664	51
12	30 55	46 57.6	1621	6765	3 56
13	24 1	46 39.5	1661	6867	4 2
14	17 31	46 20.2	1701	6070	8
15	11 21	45 59.8	1740	7075	14
16	5 32	45 38.8	1779	7181	20
17	20 0 1	45 16.9	1818	7285	26
18	19 54 50	44 56.8	1855	7388	32
19	49 56	44 37.1	1892	7492	39
20	45 20	44 16.5	1929	7596	46
21	41 0	43 57 1	1965	7702	53
22	19 36 55	−43 38.1	0.2000	9.7808	4 59

M. KAMENSKY.

VARIABLE STARS.

Minima of Variable Stars of the Algol Type.

[Given to the nearest hour in Greenwich Mean Time beginning with noon. To reduce to Central Standard time subtract 6 hours, or for Eastern time subtract 5 hours.]

U Cephei

	d	h
June	3	4
	5	16
	8	4
	10	15
	13	3
	15	15
	18	3
	20	15
	23	2
	25	14
	28	2
	30	14

Z Persei

	d	h
June	1	5
	4	6
	7	7
	10	9
	13	10
	16	12
	19	13
	22	14
	25	16
	28	17

RY Persei

	d	h
June	7	1
	13	22
	20	19
	27	15

RZ Cassiop.

	d	h
June	2	7
	3	12
	4	16
	5	21
	7	2
	8	6
	9	11
	10	16
	11	21
	13	1
	14	6
	15	10
	16	15
	17	20
	19	0
	20	5
	21	10
	22	15
	23	19
	25	0
	26	5
	27	9
	28	14
	29	19
	30	23

Algol

	d	h
June	2	6
	5	3
	8	0
	10	21
	13	18
	16	14
	19	11
	22	8
	25	5
	28	2

RT Persei

	d	h
June	1	9
	2	6
	3	2
	3	22
	4	19
	5	15
	6	12
	7	8
	8	4
	9	1
	9	21
	10	18
	11	14
	12	10
	13	7
	14	3
	14	23
	15	20
	16	16
	17	13
	18	9
	19	5
	20	2
	20	22
	21	19
	22	15
	23	11
	24	8
	25	4
	26	0
	26	21
	27	17
	28	14
	29	10
	30	6

RS Cephei

	d	h
June	3	20
	16	6
	28	16

Y Camelop.

	d	h
June	1	16
	5	0
	8	7

Y Camelop.

	d	h
June	11	14
	14	21
	18	5
	21	12
	24	19
	28	3

RR Puppis

	d	h
June	2	7
	8	18
	15	4
	21	14
	28	1

V Puppis

	d	h
June	1	12
	2	23
	4	10
	5	21
	7	8
	8	19
	10	6
	11	17
	13	4
	14	15
	16	2
	17	12
	18	23
	20	10
	21	21
	23	8
	24	19
	26	6
	27	17
	29	4
	30	15

S Cancri

	d	h
June	8	8
	17	19
	27	7

S Velorum

	d	h
June	1	18
	7	16
	13	15
	19	13
	25	12

RR Velorum

	d	h
June	1	5
	3	2
	4	22
	6	19
	8	15
	10	12
	12	8
	14	5
	16	1

RR Velorum

	d	h
June	17	22
	19	18
	21	15
	23	11
	25	8
	27	4
	29	1
	30	21

SS Carinae

	d	h
June	1	20
	5	4
	8	11
	11	18
	15	1
	18	8
	21	16
	24	23
	28	6

Z Draconis

	d	h
June	1	2
	2	10
	3	19
	5	3
	6	12
	7	20
	9	5
	10	14
	11	22
	13	7
	14	15
	16	0
	17	9
	18	17
	20	2
	21	10
	22	19
	24	3
	25	12
	26	21
	28	5
	29	13
	30	22

RZ Centauri

	d	h
June	2	16
	3	15
	4	13
	5	12
	6	10
	7	9
	8	7
	9	6
	10	4
	11	3
	12	1

RZ Centauri

	d	h
June	13	0
	13	23
	14	21
	15	20
	16	18
	17	17
	18	15
	19	14
	20	12
	21	11
	22	9
	23	8
	24	6
	25	5
	26	3
	27	2
	28	0
	28	23
	29	21
	30	20

SS Centauri

	d	h
June	2	20
	5	7
	7	19
	10	6
	12	18
	15	5
	17	17
	20	4
	22	16
	25	3
	27	14
	30	2

δ Libræ

	d	h
June	2	6
	4	14
	6	22
	9	5
	11	13
	13	21
	16	5
	18	13
	20	21
	23	5
	25	12
	27	20
	30	4

U Coronæ

	d	h
June	1	8
	4	19
	8	5
	11	16
	18	14
	22	1

Minima of Variable Stars of the Algol Type.—Continued.

U Coronæ

	d	h
June	25	12
	28	23

R Aræ

June	3	8
	7	18
	12	4
	16	14
	21	1
	25	11
	29	21

U Ophiuchi

June	1	17
	2	13
	3	9
	4	5
	5	1
	5	21
	6	17
	7	14
	8	10
	9	6
	10	2
	10	22
	11	18
	12	14
	13	10
	14	7
	15	23
	16	19
	17	15
	18	11
	19	7
	20	3
	21	0
	21	20
	22	16
	23	12
	24	8
	25	4
	26	0
	26	21
	27	17
	28	13
	29	9
	30	5

Z Herculis

June	4	6
	8	6
	12	6
	20	6
	24	5
	28	5

RS Sagittarii

June	2	20
	5	6
	7	16
	10	2

RS Sagittarii

	d	h
June	12	2
	14	22
	17	8
	19	18
	22	4
	24	14
	27	0
	29	10

V Serpentis

June	1	4
	4	15
	8	2
	11	13
	15	0
	18	11
	21	22
	25	9
	28	19

RX Herculis

June	1	8
	2	5
	3	3
	4	0
	4	21
	5	19
	6	16
	7	13
	8	11
	9	8
	10	5
	11	3
	12	0
	12	22
	13	19
	14	16
	15	14
	16	11
	17	8
	18	6
	19	3
	20	0
	20	22
	21	19
	22	16
	23	14
	24	11
	25	8
	26	6
	27	3
	28	0
	28	22
	29	19
	30	16

SX Sagittarii

June	2	20
	4	21
	6	23

SX Sagittarii

	d	h
June	9	1
	11	3
	13	5
	15	7
	17	8
	19	10
	21	12
	23	14
	25	16
	27	18
	29	20

RR Draconis

June	1	0
	3	20
	6	16
	9	12
	12	8
	15	4
	18	0
	20	20
	23	16
	26	11
	29	7

RZ Ophiuchi

June	21	12

U Scuti

June	1	11
	2	9
	3	8
	4	7
	5	6
	6	5
	7	4
	8	3
	9	2
	10	1
	11	0
	11	23
	12	22
	13	20
	14	19
	15	18
	16	17
	17	16
	18	15
	19	14
	20	13
	21	12
	22	11
	23	10
	24	9
	25	8
	26	6
	27	5
	28	4
	29	3
	30	2

RX Draconis

	d	h
June	2	5
	4	3
	6	0
	7	22
	9	19
	11	17
	13	14
	15	12
	17	9
	19	6
	21	4
	23	1
	24	23
	26	20
	28	18
	30	15

RV Lyræ

June	1	17
	5	8
	8	22
	12	12
	16	3
	19	17
	23	8
	26	22
	30	12

U Sagittarii

June	4	6
	7	15
	11	1
	14	10
	17	19
	21	4
	24	13
	27	22

SY Cygni

June	5	8
	11	8
	17	8
	29	9

WW Cygni

June	3	1
	6	9
	9	17
	13	0
	16	8
	19	16
	22	23
	26	7
	29	14

SW Cygni

June	4	20
	9	10
	14	0
	18	13

SW Cygni

	d	h
June	23	3
	27	17

VW Cygni

June	9	4
	17	14
	26	1

UW Cygni

June	2	20
	6	7
	9	18
	13	5
	16	16
	20	2
	23	13
	27	0
	30	11

W Delphini

June	4	0
	8	19
	13	15
	18	10
	23	5
	28	1

RR Delphini

June	3	0
	7	15
	12	5
	16	20
	21	10
	26	0
	30	15

VV Cygni

June	1	18
	3	6
	4	17
	6	5
	7	16
	9	4
	10	15
	12	3
	13	14
	15	2
	16	13
	18	0
	19	12
	20	23
	22	11
	23	22
	25	10
	26	21
	28	9
	29	20

UZ Cygni

June	29	19

Maxima of Variable Stars of Short Period not of the Algol Type.

Unless otherwise indicated the times of maxima only are given; and the times of minima may be found by subtracting the interval printed in parentheses under the names of the stars.

RW Cassiop.

	d	h
	(−5	19)
June	5	12
	20	7

RU Camelop.

	(−9	12)
June	16	23

V Carinæ

	(−2	4)
June	6	20
	13	13
	20	5
	26	22

T Velorum

	(−1	10)
June	5	14
	10	5
	14	20
	19	12
	24	3
	28	18

W Carinæ

	(−1	0)
June	1	9
	5	18
	10	3
	14	12
	18	21
	23	6
	27	15

S Muscæ

	(−3	11)
June	7	3
	16	18
	26	10

T Crucis

	(−2	2)
June	5	5
	11	22
	18	16
	25	10

R Crucis

	(−1	10)
June	4	2
	9	22
	15	18
	21	13
	27	9

S Crucis

	(−1	12)
June	1	3
	5	19
	10	12

S Crucis

	d	h
June	15	4
	19	21
	24	13
	29	6

W Virginis

	(−8	5)
	d	h
June	3	20
	21	2

V Centauri

	(−1	11)
June	3	15
	9	3
	14	15
	20	3
	25	15

R Triang. Austr.

	(−1	0)
June	2	21
	6	6
	9	15
	13	1
	16	10
	19	19
	23	5
	29	14
	29	23

S Triang. Austr.

	(−2	2)
June	3	10
	9	18
	16	2
	22	10
	28	17

S Normæ

	(−4	10)
June	8	12
	18	6
	28	0

RV Scorpii

	(−1	10)
June	6	14
	12	15
	18	17
	24	18
	30	19

RV Ophiuchi Minimum.

June	1	9
	5	1
	8	18
	12	10

RV Ophiuchi

	d	h
June	16	3
	19	19
	23	16
	27	8

X Sagittarii

	(−2	22)
June	5	3
	12	3
	19	3
	26	4

Y Ophiuchi

	(−6	5)
June	17	15

W Sagittarii

	(−3	0)
June	6	10
	14	0
	21	14
	29	5

Y Sagittarii

	(−2	2)
June	3	5
	8	23
	14	18
	20	13
	26	7

U Sagittarii

	(−2	23)
June	5	10
	12	4
	18	22
	25	15

β Lyræ

	(−3	2)
	(−3	7)
June	5	1
	11	17
	17	23
	24	15
	30	20

κ Pavonis

	(−1	7)
June	9	9
	18	11
	27	14

U Aquilæ

	(−2	4)
June	7	6
	14	6
	21	7
	28	8

U Vulpeculæ

	d	h
	(−2	3)
June	1	13
	9	12
	17	12
	25	11

SU Cygni

	(−1	7)
June	1	14
	5	10
	9	7
	13	3
	16	23
	20	20
	24	16
	28	12

η Aquilae

	(−2	6)
June	6	15
	13	20
	21	0
	28	4

S Sagittae

	(−3	10)
June	2	23
	11	8
	19	18
	28	3

X Vulpeculæ

	(−2	1)
June	3	0
	9	8
	15	15
	21	23
	28	7

V Vulpeculae Minimum

June	18	23

X Cygni

	(−6	19)
June	12	2
	28	12

T Vulpeculae

	(−1	10)
June	2	3
	6	13
	11	0
	15	10
	19	21
	24	7
	28	18

TX Cygni

June	10	5
	24	22

VY Cygni

	d	h
	(−2	14)
June	7	0
	14	20
	22	17
	30	13

VZ Cygni

	(−2	12)
	(−3	6)
June	3	4
	7	21
	12	21
	17	15
	22	15
	27	8

δ Cephei

	(−1	10)
June	5	5
	10	14
	15	23
	21	8
	26	16

V Lacertae

June	4	0
	9	0
	14	0
	18	23
	23	23
	28	23

X Lacertae

June	5	6
	10	16
	16	3
	21	13
	27	0

RI Cassiop.

	(−1	19)
June	1	10
	7	17
	14	0
	20	7
	26	14

RY Cassiop.

	(−7	10)
June	2	4
	14	7
	26	11

Y Lacertae

	(−1	10)
June	1	20
	6	3
	10	11
	14	18
	18	26
	23	10
	27	17

Approximate Magnitudes of Variable Stars on Apr. 1, 1908.

[Communicated by the Director of Harvard College Observatory, Cambridge, Mass.]

Name.	R. A. 1900. h	m	Decl. 1900. °	′	Magn.	Name.	R.A. 1900. h	m	Decl. 1900. °	′	Magn.
X Androm.	0	10.8	+46	27	<13	X Gemin.	5	40.7	+30	23	11.0
T Androm.		17.2	+26	26	9.0*d*	W Monoc.		47.5	− 7	2	10.7
T Cassiop.		17.8	+55	14	2.0*d*	Y Monoc.		51.3	+11	22	11.4 *i*
R Androm.		18.8	+38	1	13.0 *i*	X Monoc.		52.4	− 8	56	7.6
Y Cephei		31.3	+79	48	12.5	R Lyncis		53.0	+55	28	12.0*d*
U Cassiop.		40.8	+47	43	8.3 *i*	RS Gemin.		55.2	+30	40	11.2
RW Androm.		41.9	+32	8	10.0 *i*	V Can. Min.	7	1.5	+ 9	2	<14
V Androm.		44.6	+35	6	9.6 *i*	R Gemin.		1.3	+22	52	<13.5
RR Androm.		45.9	+33	50	<12.6	R Can. Min.		3.2	+10	11	8.4
RV Cassiop.		47.1	+46	53	<12.6	RR Monoc.		12.4	+ 1	17	<13.5
W Cassiop.		49.0	+58	1	10.0 *i*	V Gemin.		17.6	+13	17	11.0*d*
RX Androm.		58.9	+40	46	13.0	S Can Min.		27.3	+ 8	32	12.0
U Androm.	1	9.8	+40	11	11.0 *i*	T Can. Min.		28.4	+11	58	14.0 *i*
S Cassiop.		12.3	+72	5	12.4 *i*	Z Puppis		28.3	−20	57	13.3
RU Androm.		32.8	+38	10	<12.6	U Can. Min.		35.9	+ 8	37	10.3*d*
Y Androm.		33.7	+38	50	<12.6	S Gemin.		37.0	+23	41	12.5 *i*
X Cassiop.		49.8	+58	46	9.6*d*	T Gemin.		43.3	+23	59	10.5*d*
U Persei		53.0	+54	20	8.2	U Puppis		56.1	−12	34	13.6*d*
R Arietis	2	10.4	+24	35	12.0*d*	R Cancri	8	11.0	+12	2	11.8*d*
W Androm.		11.2	+43	50	<13	V Cancri		16.0	+17	36	11.6*d*
Z Cephei		12.8	+81	13	<13	RT Hydrae		24.7	− 5	59	9.4*d*
o Ceti		14.3	− 3	26	8.3*d*	U Cancri		30.0	+19	14	<13
S Persei		15.7	+58	8	8.6	X Urs. Maj.		33.7	+50	30	9.6 *i*
R Ceti		20.9	− 0	38	8.6	S Hydrae		48.4	+ 3	27	7.7 *i*
RR Cephei		30.4	+80	42	<13	T Hydrae		50.8	− 8	46	8.7*d*
R Trianguli		31.0	+33	50	5 6 *i*	T Cancri		51.0	+20	14	9.6*d*
T Arietis		42.8	+17	6	8.7	S Pyxidis	9	0.7	−24	41	11.6*d*
W Persei		43.2	+56	34	9.6*d*	W Cancri		4.0	+25	39	12.6*d*
U Arietis	3	5.5	+14	25	10.0*d*	X Hydrae		30.7	−14	15	12.0*d*
X Ceti		14.3	− 1	26	10.0*d*	Y Draconis		31.1	+78	18	<13
Y Persei		20.9	+43	50	9.4*d*	R Leo. Min.		39.6	+34	58	11.0*d*
R Persei		23.7	+35	20	10.3 *i*	RR Hydrae		40.4	−23	34	<13.4
T Tauri	4	16.2	+19	18	12.0*d*	R Leonis		42.2	+11	54	8.6*d*
R Tauri		22.8	+ 9	56	<13	Y Hydrae		46.4	−22	33	6.5
W Tauri		22.2	+15	49	9.6*d*	V Leonis		54.5	+21	44	<13.5
S Tauri		23.7	+ 9	44	10.4	R Urs. Maj.	10	37.6	+69	18	13.0*d*
T Camelop.		30.4	+65	57	8.6	W Leonis		48.4	+14	15	<13
RX Tauri		32.8	+ 8	9	<13	V Hydrae		46.8	−20	43	10.0
X Camelop.		32.6	+74	56	13.5*d*	S Leonis	11	5.7	+ 6	0	10.8*d*
V Tauri		46.2	+17	22	11.0*d*	R Comae		59.1	+19	20	14.0
R Orionis		53.6	+ 7	59	10.8*d*	T Virginis	12	9.5	− 5	29	13.6
R Leporis		55.0	−14	57	9 6 *i*	R Corvi		14.4	−18	42	10.5 *i*
V Orionis	5	0.8	+ 3	58	12.6 *i*	T Can. Ven.		25.2	+32	3	11.2 *i*
T Leporis		0.6	−22	2	10.6 *i*	Y Virginis		28.7	− 3	52	10.4 *i*
R Aurigae		9.2	+53	28	11.4*d*	T Urs. Maj.		31.8	+60	2	11.5*d*
S Aurigae		20.5	+34	4	9.0 *i*	R Virginis		33.4	+ 7	32	10.4*d*
W Aurigae		20.1	+36	49	11.6*d*	RS Urs. Maj.		34.4	+59	2	9.6*d*
S Orionis		24.1	− 4	46	13.0*d*	S Urs. Maj.		39.6	+61	38	9.6*d*
T Orionis		30.9	− 5	32	9.5	RU Virginis		42.2	+ 4	42	9.0 *i*
S Camelop.		30.2	+68	45	8.8 *i*	U Virginis		46.0	+ 6	6	10.4 *i*
RR Tauri		33.3	+26	19	11.5	RT Virginis		57.6	+ 5	43	8.6
U Aurigae		35.6	+31	59	11.0 *i*	RV Virginis	13	2.8	−12	38	<13.5
Z Tauri		46.7	+15	46	<13	V Virginis		22.6	− 2	39	10.4*d*
V Camelop.		49.4	+74	30	<13	R Hydrae		24.2	−22	46	8.4 *i*
Z Aurigæ		53.6	+53	18	10.4 *i*	S Virginis		27.8	− 6	41	11.0*d*
X Aurigae		4.4	+50	15	9.6 *i*	T Urs. Min.		32.6	+73	56	12.6*d*
V Monoc.		17.7	− 2	9	11.4 *i*	R Can. Ven.		44.6	+40	2	10.8*d*
V Aurigae		16.5	+47	45	9.6*d*	RR Virginis		49.6	− 8	43	<13.5
R Monoc.		33.7	+ 8	49	11.0	Z Bootis	14	1.3	+13	59	9.8 *i*
S Lyncis		35.9	+58	0	13.6	Z Virginis		5.0	−12	50	10.8

Approximate Magnitudes of Variable Stars on Apr. 1, 1908—Con.

Name.	R. A. 1900. h m	Decl. 1900. ° ′	Magn.	Name.	R. A 1900 h m	Decl. 1900 °	Magn.
U Urs. Min.	14 15.1	+67 15	11.5*d*	RV Herculis	16 56.8	+31 22	11.0 *i*
S Bootis	19.5	+54 16	8.6 *i*	R Ophiuchi	17 2.0	−15 58	11.0*d*
RS Virginis	22.3	+ 5 8	12.6*d*	RT Herculis	6.8	+27 11	11.6 *i*
V Bootis	25.7	+39 18	9.3*d*	Z Ophiuchi	14.5	+13 7	12.6*d*
R Camelop.	25.1	+84 17	8.4*d*	RS Herculis	17.5	+23 1	10.5 *i*
R Bootis	32.8	+27 10	12.2*d*	RU Ophiuchi	28.1	+ 9 30	12.0*d*
V Librae	34.8	−17 14	11.0*d*	RS Ophiuchi	44.8	−.6 40	11.0
U Bootis	49.7	+18 6	12.5*d*	RT Ophiuchi	51.8	+11 11	<13.2
RT Librae	15 0.8	−18 21	13.0*d*	T Draconis	54.8	+58 14	10.6
T Librae	5.9	−19 38	10.8 *i*	RY Herculis	55.4	+19 29	9.4*d*
Y Librae	6.4	− 5 38	12.6	V Draconis	56.3	+54 53	10.2 *i*
S Librae	15.6	−20 2	10.2*d*	T Herculis	18 5.3	+31 0	11.8 *i*
S Serpentis	17.0	+14 40	12.0 *i*	W Draconis	5.4	+65 56	10.0
S Coronae	17.3	+31 44	9.2*d*	X Draconis	6.8	+66 8	10.2
RS Librae	18.5	−22 33	11.5*d*	W Lyrae	11.5	+36 38	9.6
RU Librae	27.7	−14 59	11.2 *i*	T Serpentis	23.9	+ 6 14	<12.5
X Librae	30.4	−20 50	10.5 *i*	X Ophiuchi	33.6	+ 8 44	8.0
S Urs. Min.	33.4	+78 58	9.0 *i*	RY Lyrae	41.2	+34 34	<12.5
U Librae	36.2	−20 52	9.3 *i*	RW Lyrae	42.1	+43 32	<12.5
Z Librae	40.7	−20 49	13.0	Z Lyrae	56.0	+34 49	<12.5
R Coronae	44.4	+28 28	5.8	RX Lyrae	50.4	+32 42	<12.5
X Coronae	45.2	+36 35	12.5*d*	RW Cygni	25.2	+39 39	8.6*d*
R Serpentis	46.1	+15 26	10.6 *i*	RT Lyrae	57.8	+37 22	12.0
V Coronae	46.0	+39 52	7.8	R Aquilae	19 1.6	+ 8 5	10.6*d*
R Librae	47.9	−15 56	<13	V Lyrae	5.2	+29 30	11.8
RR Librae	50.6	−18 1	10.6*d*	RS Lyrae	9.3	+33 15	11.0
— Coronae	52.2	+29 32	13.5	RY Ophiuchi	11.6	+ 3 40	<12.6
RZ Scorpii	58.6	−23 50	9.3 *i*	RU Lyrae	9.1	+41 8	12.0
Z Scorpii	16 0.1	−21 28	10.3 *i*	U Draconis	9.9	+67 7	11.0 *i*
R Herculis	1.7	+18 38	9.0 *i*	U Lyrae	16.6	+37 42	10.3 *i*
RR Herculis	1.5	+50 46	9.6*d*	TY Cygni	29.8	+28 6	11.4 *i*
U Serpentis	2.5	+10 12	9.6 *i*	R Cygni	34.1	+49 58	<13
X Scorpii	2.7	−21 16	12.4*d*	RV Aquilae	35.9	+ 9 42	9.4 *i*
W Scorpii	5.9	−19 53	<13	RT Aquilae	33.3	+11 30	13.8
RX Scorpii	5.9	−24 38	12.6*d*	RT Cygni	40.8	+48 32	12.8*d*
RU Herculis	6.0	+25 20	12.8	TU Cygni	43.3	+48 49	10.6 *i*
R Scorpii	11.7	−22 42	<13	χ Cygni	46.7	+32 40	6.0 *i*
S Scorpii	11.7	−22 39	<13	Z Cygni	58.6	+49 46	10.6*d*
W Coronae	11.8	+38 3	12.2	U Cygni	20 16.5	+47 35	7.8 *i*
V Ophiuchi	21.2	−12 12	7.7 *i*	X Cephei	21 3.6	+82 40	13.4 *i*
U Herculis	21.4	+19 7	12 0 *i*	T Cephei	8.2	+68 5	7.0 *i*
Y Scorpii	23.8	−19 13	11.5 *i*	S Cephei	36.5	+78 10	7.8 *i*
SS Herculis	28.0	+ 7 3	9.5	S Lacertae	22 24.6	+39 48	13.0*d*
S Ophiuchi	28.5	−16 57	13.0*d*	R Lacertae	38.8	+41 51	11.0 *i*
T Ophiuchi	28.0	−15 55	9.0 *i*	V Cassiop.	23 7.4	+59 8	8.6 *i*
W Herculis	31.7	+37 32	13.5*d*	RR Cassiop.	50.7	+53 8	12.2*d*
R Draconis	32.4	+66 58	7.5 *i*	R Cassiop.	53.3	+50 50	12.2*d*
RR Ophiuchi	43.2	−19 17	10.5*d*	Y Cassiop.	58.2	+55 7	10.6 *i*
S Herculis	47.4	+15 7	9.6*d*				

The letter *i* denotes that the light is increasing, the letter *d* that the light is decreasing, the sign <, that the variable is fainter than the appended magnitude.

The magnitudes given above have been compiled by Mr. Leon Campbell of the Harvard College Observatory, from observations made at the Vassar, Mt. Holyoke, Whitin and Harvard Observatories.

New Variable 6.1908 Geminorum.—In *A. N.* 4237 Professor Ceraski announces as a new variable the star BD. + 15° 1573. Its magnitude as given in the BD is 9.0. Upon 17 photographs taken at Moscow in 1899-1907 it appears of constant magnitude, about 9.0, but upon 4 plates it is

PLATE XX

28-in. Reflector 1907 Aug. $14^d\ 15^h\ 8.2^m$

1¼-in. Lens 1907 Aug. $14^d\ 15^h\ 0.2^m$

COMET *d* 1907 (DANIEL), MAX WOLF
HEIDELBERG

fainter. On the photographs taken March 18 and 24, 1903 and March 11, 1904, it appears only a few tenths of a magnitude fainter, but upon that of April 5, 1907 it is 1½ magnitudes below the normal. It is probably of the Algol Type. Its position is

1855.0	$\alpha = 7^h\ 19^m\ 07^s.32$	$\delta = +15^\circ\ 56'\ 50''.1$
1900.0	7 21 41 .68	+15 51 39 .9

Approximate Elements of Three Variables. In *A. N.* 4238 Mr. S. Enebo of Dombaas, Norway, gives the following approximate elements depending upon his own observations;

79.1907	Aurigæ	Min. = 1907 Oct. 4 8^h	Gr.m.t.	$+1^h\ 12^m\ 48^s$ E
		= 2417853.375	"	$+1^d.533$ E
80.1907	Aurigæ	Max. = 1907 Sept. 14	"	$+10^d\ 21^h$ E
		= 2417833	"	$+10^d.9$ E
142.1907	Cassiopeiæ	Min. = 1907 Nov. 30 9^h	"	
		= 2417910.4	"	$+36^d4$ E

The range of brightness of 79.1907 is $8^m.0 - 8^m.7$, that of 80.1907, $9^m.0 - 9^m.7$ and that of 142.1907, 8.8 — 9.6. The last apparently belongs to the Algol type and the change of light at minimum occupies at least three days.

GENERAL NOTES.

Photographs of Daniel's Comet *d* 1907.—In *Monthly Notices* of R. A. S. for January 1908 are reproductions of two beautiful photographs of this comet taken at Heidelberg by Professor Max Wolf on August 14, 1907. One taken with a 1¼-inch lens shows a tail twelve degrees long. The other, taken with a 28-inch reflector, shows the head and tail for about one degree from the nucleus. In this portion of the tail one can count from fifteen to twenty bright streaks separated by dark ones emanating from the head of the comet.

Professor Wolf says that photographs of the comet were taken at Heidelberg on ten nights from July 21 to August 27, and that he also made drawings of the comet as seen with the 28-inch reflector on six of the same nights. The following remark made by Professor Wolf is interesting:

"The most striking result appears to me the difference between the visual and the photographic appearances. All the drawings show a minimum of luminous radiation in or around the axis of the tail in the region turned away from the Sun. All the photographs show the brightest tails near the axis, exactly in the parts where visually there was a minimum of brightness. This very curious difference, which was remarked several years before in other comets photographed here seems to be placed beyond doubt by the photographs taken with the reflector.

"Besides this, it is very interesting, and perhaps in opposition with accepted theories, that the short arms of the tails furthest outside the axis are nearly all curved".

"Mirage" from Blast Furnaces. I have read in the Literary Digest a comment on an article by Mr. William E. Sperra published in your number for March relating to a "mirage" from blast-furnaces at Newburg, Ohio.

Having spent some years in the vicinity of steel mills and observed similar lights in the sky on numerous occasions I would like to suggest a possible explanation of the phenomenon.

The mouth of a Bessemer converter does not open directly upward but is inclined at possibly 30° and from this opening a beam of light is projected

which becomes of exceeding intensity at the height of the blast. On a night when a slight haze or mist is present in the atmosphere this beam is visible like the beam from a search light from the mouth of the converter to a great altitude, while on a perfectly clear night it is wholly invisible. On nights which appear to be thus perfectly clear and starlit there are frequently very slight clouds in the upper atmosphere which become visible upon receiving any illumination from beneath. If we were able to observe the cloud from directly in line with the converter we should see a single round spot of light reflected there but due to the inclination of this ray and the obliquity of our line of vision this spot appears elongated and most intense near its center. This brightness varies greatly during the period of blast and, of course disappears entirely during the interval when the particular converter is out of blast. The fact that only the portion of the cloud in line with the beam receives any light causes this spot to appear with no background other than the starlit heavens.

Ithaca, N. J. LESLIE D. HAYES.

Sale of Instruments from Manora Observatory. The following notice is received: "The Manora Observatory will be sold within a few months. That gives an opportunity to our readers of acquiring the 7-inch equatorial with accessories at a relatively moderate price. The extraordinary performances of that instrument are known. It showed the satellites of Mars, Uranus and Neptune, Hyperion, permitted the measurement of the companion of Sirius, when it was shown only by the Lick equatorial (distance 3″.74) and of β 79 (distance 0.″56), dissolved the Great Andromeda Nebula into stars, enabled Mr. Brenner to discover 200 new objects on Mars, and was declared by all astronomers who examined it, to be an incomparable instrument."

Relation Between the Color and the Period of Variable Stars. It has been known for some years that there is an intimate relation between the colors and the periods of variable stars. The appearance of Professor Pickering's second catalogue of variable stars (*Harvard Annals* 55), with color data for about 300 stars, led Mr. S. Beljawsky, of the observatory at Göttingen, to undertake a new study of the subject. His results are given in *A. N.* 4238.

The color estimates of all the observers concerned were made on one of the two scales adopted by Chandler and Osthoff. For an approximate reduction of the one scale to the other Mr. Beljawsky adopted the numerical relation indicated in Table I.

TABLE I

Color	Scale	
	Osthoff	Chandler
White	0	0
	1[c]	0.5[c]
	2	1.0
	3	1.5
Pure Yellow	4	2.0
	5	2.6
	6	3.3
Orange	7	4.2
	8	5.4
	9	7.2
Pure Red	10	10.0

After reducing the estimates made according to Chandler's scale to make them correspond with Osthoff's scale, the averages of the color numbers were

taken in groups according to the class of the star and the length of its period. These averages are collected in Table II, and those of classes IV and II are plotted in Figure 1. The numbers of Table II are represented by the round dots. Their progress is followed roughly by the dotted line which is almost straight.

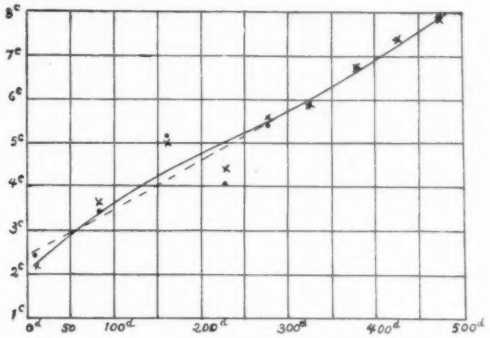


FIGURE 1

TABLE II

Class	Period	Mean Period	Mean Color	No. of Stars
			c	
V	Algol Type	—	0.83	13
IV	Short Period	10	2.44	20
II	$<100^d$	80	3.4	4
"	$100^d - 200^d$	163	5.11	24
"	200 — 250	226	4.07	34
"	250 — 300	274	5.45	35
"	300 — 350	325	5.83	49
"	350 — 400	374	6.70	36
"	400 — 450	418	7.38	24
"	450 — 500	474	7.9	7
III	Irregular	—	7.29	44

In Table III the stars are grouped according to declination north and south of the equator. The results show no marked tendency of the colors of these stars to vary systematically with the declination. If the zone from 0° to 30° north declination were considered alone there would be an apparent systematic change but when the entire range north and south is taken into account the systematic character of the change disappears.

TABLE III

Decl.	Color	Mean Period	No. of Stars
°	c	d	
— 56	6.37	300	16
— 38	6.53	284	14
— 24	4.90	286	16
— 16	5.74	301	18
— 5	6.05	300	13
+ 6	4.83	309	23
+ 12	5.26	323	15
+ 17	5.63	284	17
+ 24	6.56	280	12
+ 35	5.63	282	16
+ 44	6.05	331	12
+ 54	6.15	336	13
+ 68	5.67	309	9

The average color number for a northern star is 5c.70
" " " " " " southern " " 5 .89

It is evident from Table III that the average period of the known variables of class II is in the vicinity of 300 days. After the color numbers of those stars in Table II had been reduced to the period 300 days by means of the curve in Figure 1 they were again grouped according to their brightness. The results of this grouping are given in Table IV and plotted in Figure 2. They show considerable inter-dependence between color and magnitude.

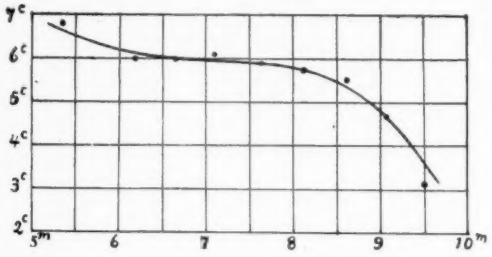


FIGURE 2

TABLE IV

Limits of Mag.	Mean Magnitude	Color	No. of Stars
	m	c	
>6	5.3	6.8	11
6.0 — 6.4	6.22	6.0	10
6.5 — 6.9	6.66	6.0	17
7.0 — 7.4	7.10	6.10	27
7.5 — 7.9	7.66	5.90	32
8.0 — 8.4	8.12	5.75	46
8.5 — 8.9	8.62	5.56	33
9.0 — 9.4	9.07	4.65	26
9.5 — 9.9	9.5	3.1	4

In view of the dependence of the color upon the brightness of the star, those brighter than the 5th magnitude and fainter than 9.5, were omitted from the further discussion. A new reduction of the color numbers in Table II was made and the means given in Table V are represented by the crosses in Figure 1.

TABLE V

Mean Period	Mean Color	No. of Stars
d	c	
13	2.2	13
80	3.6	4
163	5.04	22
226	4.44	32
274	5.62	34
325	5.79	47
374	6.64	35
418	7.30	21
474	7.8	7
Irregular	7.85	26

Finally Mr. Beljawsky compared the periods of the variables with the amplitude of their variation in magnitude, finding that the amplitude increases with the period up to a period of about 200 days. Beyond 250 days the

data concerning the amplitude of variation are too incomplete to be used in the discussion. The results of this comparison are shown in Table VI and Figure 3.

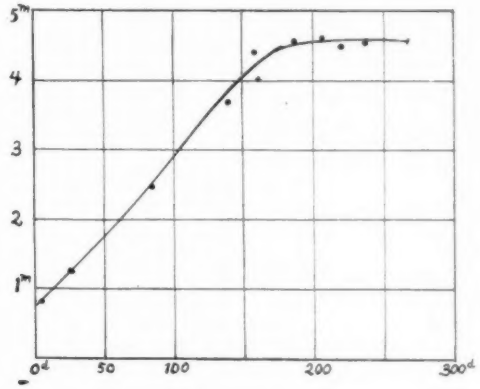


FIGURE 3

TABLE VI

Limits of Period d — d	Mean Period d	Amplitude m	No. of Stars
0 — 10	4.6	0.83	48
10 — 40	23.0	1.23	15
50 — 100	84	2.5	6
100 — 150	140	3.75	15
150 — 175	163	4.40	12
175 — 200	187	4.60	13
200 — 214	206	4.67	19
214 — 225	220	4.53	17
225 — 250	237	4.58	30

The Great Nebula in Andromeda. In the April number of *Knowledge* is found a very interesting article by J. Ellard Gore. We can only refer to some points in it. He says if we assume the parallax of the nebula to be about one one-hundredth of a second of arc it would still be within the bounds of our sidereal system, about 326 light years in distance from us, whereas the remote portions of the Milky Way must be at a distance of about 3000 light years. This assumed parallax is probably too large, for it would make its mass eight thousand million times as great as the mass of the Sun.

Mr. Gore calls attention to the fine photograph of this nebula by Dr. Roberts and notices in it several faint stars. It is impossible to tell whether the nebula is in the same order of distance as these small stars, for some of them seen between its branches may be farther away and others may be projected on the nebula.

The study of the spectrum of this nebula is interesting though difficult. It shows that its mass is not wholly gaseous. According to Scheiner, its spectrum is continuous, similar to the solar spectrum, and the greater part

of the stars composing the nucleus, he thinks belongs to the second spectral class. According to his view this would mean that the nebula is in an advanced stage of development. No trace of bright nebular lines are present so that the interstellar space in the great nebula, "just as in our stellar system, is not appreciably occupied by gaseous matter."

Mr. Gore examines the suggestion that the Andromeda nebula may be an external universe outside of our sidereal system and comparable in size with it. If the diameter of the Milky Way is 6000 light years, and that of the Andromeda nebula is of the same size, Mr. Gore finds that its distance from us would be 150,000 light years. But this distance is 8000 times as great, as that indicated by Bohlin's parallax hence the relative size to that found above would be 8000 cubed which would mean a mass equal to four trillion times the Sun's mass. This seems so incredibly large that it must be rejected, and that the view of an external universe for the place of the Andromeda nebula is highly improbable.

"Mr. Gore concludes this interesting article as follows:—

It is evident, however, that the mass of the Andromeda must be enormous, and if it belongs to our sidereal system, and if the other great nebulae have similar masses, it seems quite possible that the mass of the *visible* universe may much exceed that of the visible *stars*, and may be equal to 1,000 million times the Sun's mass—as supposed by Lord Kelvin—or even much more.

In August, 1885, a star of about the seventh magnitude blazed out close to the nucleus of the Andromeda nebula. The new star was independently discovered by several observers towards the end of August. It was not visible to Temple at the Florence Observatory on August 15 and 16, but is said to have been seen on August 17 by M. Ludovic Gully. It was, however, certainly seen by Mr. T. W. Ward at Belfast, Ireland, on August 19 at 11 p.m., when he estimated it 9½ magnitude, and it was independently detected by M. Lajoye on August 30, by Dr. Hartwig at Dorpat on August 31, and by Mr. G. T. Davis at Theale, near Reading, on September 1. On September 3 the star was observed as 7½ magnitude at Dun Echt Observatory by Lord Crawford and Dr. Copeland, and its spectrum was found to be "fairly continuous." On September 4, Mr. Maunder, at the Greenwich Observatory, found the spectrum "of precisely the same character as that of the nebula, *i. e.*, it was perfectly continuous, no lines, either bright or dark, being visible, and the red end was wanting." Dr. Huggins, however, on September 9, thought he could see some bright lines in its spectrum. The star gradually faded away, and on February 7, 1886, was estimated as only 16th magnitude with the 26-inch refractor of the Washington Observatory. From a series of measures made by Professor Asaph Hall he found "no certain indications of parallax." Professor Seeliger has investigated the decrease in the light of this star on the hypothesis that it was a cooling body which had been suddenly raised to an intense heat by the shock of a collision, and finds an agreement between theory and observation. Professor Auwers points out the similarity between this outburst and the new star of 1860, which appeared in the cluster 80 Messier, and thinks it very probable that both phenomena were due to physical changes in the nebulæ in which they occurred.

The appearance of this temporary star in the Andromeda nebula seems to be further evidence against the hypothesis of the nebula being an "external universe." For, as I have shown above, our Sun placed at a distance of 150, 000 light years would shine only as a star of the 23rd magnitude, or over 15 magnitudes fainter than the temporary star. This would imply that

the star shone with a brightness of over a million times that of the Sun, and would, of course, indicate a body of enormous size. But the rapid fading away of its light would, on the contrary imply a body of comparatively small size. We must, therefore, conclude that the nebula, whatever it may be, is not an external universe, but probably forms a member of our sidereal system."

The Sun's Radiation Less than Supposed. In an article in the Los Angeles *Times* by J. E. Watkins of date April 5, 1908, are found some surprising statements in regard to the radiation of the Sun, which are credited to Mr. Abbott, said to be in charge of the U. S. Astrophysical Observatory on Mount Wilson California.

In this article Mr. Abbott claims that exaggerated estimates of the Sun's radiation which reaches the Earth have prevailed during the last thirty years.

From his measurements he claims that it is not more than half as much as formerly supposed, and only about half as much as Professor Langley determined in the course of his study of this difficult physical problem.

Head of Southern Observatory. The superintendence of the work at the proposed Southern Observatory of the Carnegie Institution has been offered to Astronomer R. H. Tucker, of the Lick Observatory, at present in acting charge of the latter, during the absence of the director.

The plan of observing is the design of Lewis Boss, director of the Dudley Observatory at Albany, who has been engaged for many years in the observation and reduction of a large and accurate fundamental catalogue of stars. The work of the Southern Observatory will include the stars that are too far south to be measured at the observatories of the northern hemisphere. It is expected that three years will be required for the plan, and the Southern station will be located either in New Zealand, South America, or South Africa. The party will probably consist of seven observers, several of whom have already been engaged.

The selection of one of the Lick Observatory staff for the prosecution of this work is one of the instances of the recognition of the standing of this institution in professional work that have not been uncommon of late. The requirements of this particular plan are mainly those of experience, technical skill, and persistence in the execution of a scheme of work. The work of a large observatory is very much specialized, just as professional work has developed in other lines.

It was as an observer, specially trained, that Mr. Tucker was invited, fifteen years ago, to join the Lick Observatory force, and to take charge of the Meridian Circle and its work. Three quarto volumes have been since published, entirely devoted to the results of the observations made with this instrument during this period at the Lick Observatory. The work is of the character that has been fundamental in the development of our knowledge of the universe of stars and in tracing the motions of the planets of our complex solar systen. The larger observatories in all parts of the world have always a force of astronomers working along this line. The smaller observatories rarely do any of this class of work.

This present expedition suggests, in a way, the early trip of Lieutenant Gilliss to Chile, to observe the southern stars; and the much more extensive and successful scheme of Dr. B. A. Gould, both of which eventually resulted in the

foundation of national observatories at Santiago, Chile, and at Cordoba, Argentine Republic, respectively. There were earlier expeditions to the Cape of Good Hope, the first of LaCaille, and, later, one of Herschel which led to the establishment of Royal Observatory at Cape Town, now one of the finest in the world. The present scheme is expeditionary only, and the equipment will be brought back to this country when the specific work is completed.

The large Pistor and Martins Meridian Circle, of the Dudley Observatory, will be used for the Southern plan, and it introduces some feeling of sentiment from the fact that the first professional observations of the astronomer, who is to take charge of this work, were made with that instrument.

Should San Luis, in the Argentine Republic, be finally selected as the observing station, there would be additional fitness in the working out of the scheme, since it was from the National Observatory at Cordoba, two hundred miles distant, that the observer came here, fresh from nine years' service under the southern skies.

The Mills Expedition, of the Lick Observatory, is now located at Santiago, under the charge of Dr. H. D. Curtiss ; and while the Cordillera of the Andes would lie between the two stations, making a barrier of no ordinary magnitude, the two stations might easily get into touch with each other, by exchanging compliments. The work of the two stations does not conflict in any way; the established one is for the physical investigation of Southern Stars, by means of the spectroscope; the new one will confine its work to the measurement of the position of the stars.—*San Jose Mercury*, January 24th.

Occultations by the Moon in Præsepe a record of some recent observations which I made. I used a four-inch alt-azimuth refractor, which I had made in Toronto last year. The objective I bought in 1906, and finding it to give satisfactory results, had the instrument constructed. Some time if you wish I will give a description of its construction; also of a nine and one-half-inch reflecting telescope the glass speculum of which I ground myself by hand, and figured it also; and which I am now building, although it is not yet completed.

On April 4, in the evening I observed the conjunction of the Moon, Venus and Mars. When seeing became good in the evening, conjunction had been passed a little; but the three bodies were quite close, and presented an interesting view in the western sky. The irradiation about Venus prevented anything being seen on the planet's surface, as is almost always the case, when that planet is in the field. The Moon however was wonderfully clear and distinct. The dark part of the Moon was perfectly visible, and details on the surface of the dark part were very noticeable. Mare and mountains were quite easily seen, and the boundaries of seas and plains were quite marked. Even the rays radiating from Plato could be easily identified. The Moon was then 5 days old. Later in the evening the sky grew cloudy, obscuring all celestial objects.

On April 9, I observed within the space of one hour, five occultations of stars by the Moon. The Moon was then in Cancer, and by 11 p. m. had approached close to the cluster known as Præsepe. The first two stars occulted were probably 8th magnitude stars, for they were very small, much smaller than the last two, which are given as magnitudes 6.5 each in the Nautical Almanac. Then a still smaller star was occulted, after the first two, the third one being perhaps a ninth or even a tenth magnitude star. It was so faint that it became an effort to follow it continuously, but I kept it in

view until occultation occurred. Then the two 6.5 magnitude stars followed, the one about 8 minutes in advance of the other. At first I had difficulty in fixing my sight on the outline of the dark portion of the Moon, which, of course fades into indistinctness after about the fifth day in age of the Moon, but, by keeping the bright part of the Moon just outside of the field, I was able to judge very closely the time when the occultation was likely to occur. In each case the extinction of the star's light was seemingly instantaneous, there being no "hanging" of the star on the Moon's edges as observers have frequently noticed; nor was there a dimming of the light before extinction, as also has been said to frequently occur.

Had I remained observing longer, I think other occultations would have been witnessed, for the path of the Moon lay close to a part of the cluster where the stars were numerous, and which would probably have been eclipsed by the Moon in its way across the sky.

I never read of so many occultations having been seen within so short a period before, and therefore have made this account of them. The first occultation occurred at 11:10 p. m., and the fifth took place at 11:38 p. m. I did not keep a minute record of the times of each of the occultations. My observations were conducted with the 4-inch glass, and the magnifying power was about 100.

Toronto, Canada.

ALBERT R. J. F. HASSARD.

A Relation of Mass to Energy.* In a paper of which this is an abstract it is shown that the momentum of any purely electric system having any internal motions and constraints, but possessing on the whole a kind of average symmetry, is given by the expression

$$M = \frac{2W_1 v}{V^2\left[1 + \left(\frac{v}{V}\right)^2\right]}.$$

Here M is the momentum of the system, (v) its velocity as a whole, V the velocity of light and W_1 the part of the total electromagnetic energy which is represented by the components of the electric and magnetic forces which lie perpendicular to the direction of motion of the system. This is a highly general result and is obtained by a method involving the generalized constraints of the system.

When the second order of the ratio v/V may be neglected, W_1 is equal to two thirds the total electromagnetic energy (W) of the system (because of the average symmetry before mentioned) and hence we have

$$\text{Mass} = \frac{4}{3}\frac{\text{I}}{V^2} W.$$

This gives the electromagnetic mass of the system in terms of its total content.

If the electrical theory of matter be accepted this result applies to the mass of any piece of matter and we have the mass proportional to the total contained energy.

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* Abstract of a paper presented at the Chicago meeting of the Physical Society, December 30, 1907, to January 2, 1908.

It is shown that if this hypothesis is accepted the irregularities which exist in the table of atomic weights are in harmony with the evolutionary theory of the elements.

Also on this basis gravitation must be considered as acting between quantities of confined energy and not between masses in any other sense.

Comparison Stars for U Geminorum. Harvard College Observatory Circular number 136 contains a list of twenty-two comparison stars with a table of results that will be useful for those wishing such information up to date of March 30, 1908.

Doctor of Science. We are pleased to notice that during the past year Bates College, Lewiston, Maine, has conferred upon O. C. Wendell, now at Harvard Observatory, the richly deserved honor of the degree of Doctor of Science.

The Hough Double Stars by Eric Doolittle. A useful publication by the University of Pennsylvania, in the Astronomical Series Vol III, part III, is just received. It is by Professor Eric Doolittle of Flower Observatory, and is a catalogue and remeasurement of 648 double stars discovered by Professor G. W. Hough, now director of the Dearborn Observatory at Evanston, Ill., since the year 1881. Professor Doolittle speaks of the neglect of the Hough double stars as follows:

"When making up a new observing list for the Flower Observatory in 1899, it was decided to include all Hough pairs in which prior measures had indicated motion as well as those which did not seem to have been adequately measured elsewhere. It soon became evident that the entire list had been remarkably neglected. Of the 490 pairs which have now been published for 13 years, there are but 17 which have been systematically observed, and of these no less than 11 are certainly entirely fixed. Altogether, 383 of these pairs have never been measured except by the discoverer himself, and of these, 199 have only been measured the year of discovery, and 43 only on a single night, or not measured at all.

This neglect is perhaps due to the fact that these close pairs, and those of very unequal magnitude in which motion was shown, are about as difficult as the stars discovered by Mr. Burnham. The number of pairs of this kind, especially since the discoveries of Hussey and Aitken, is becoming so great that it is perhaps not surprising that a large proportion of them are to some extent neglected. It is true that when Hough's first catalogue was published, his own and Mr. Burnham's discoveries comprised a very large proportion of the stars of this type, but since such pairs can in general only be reached with moderately large telescopes, and even with these only when atmospheric conditions are unusually favorable, the proportion of the pairs to the number of observers and to the number of available nights was large. Beside this, the long list of measures at the end of Catalogues III and IV may have led to the impression that Hough himself was adequately observing his own stars; without specially looking the matter up it could not be ascertained that many of them were wholly neglected. Mr. Burnham's new general catalogue, when it is published, unquestionably will greatly increase the efficiency of double star work in this respect for many years to come."